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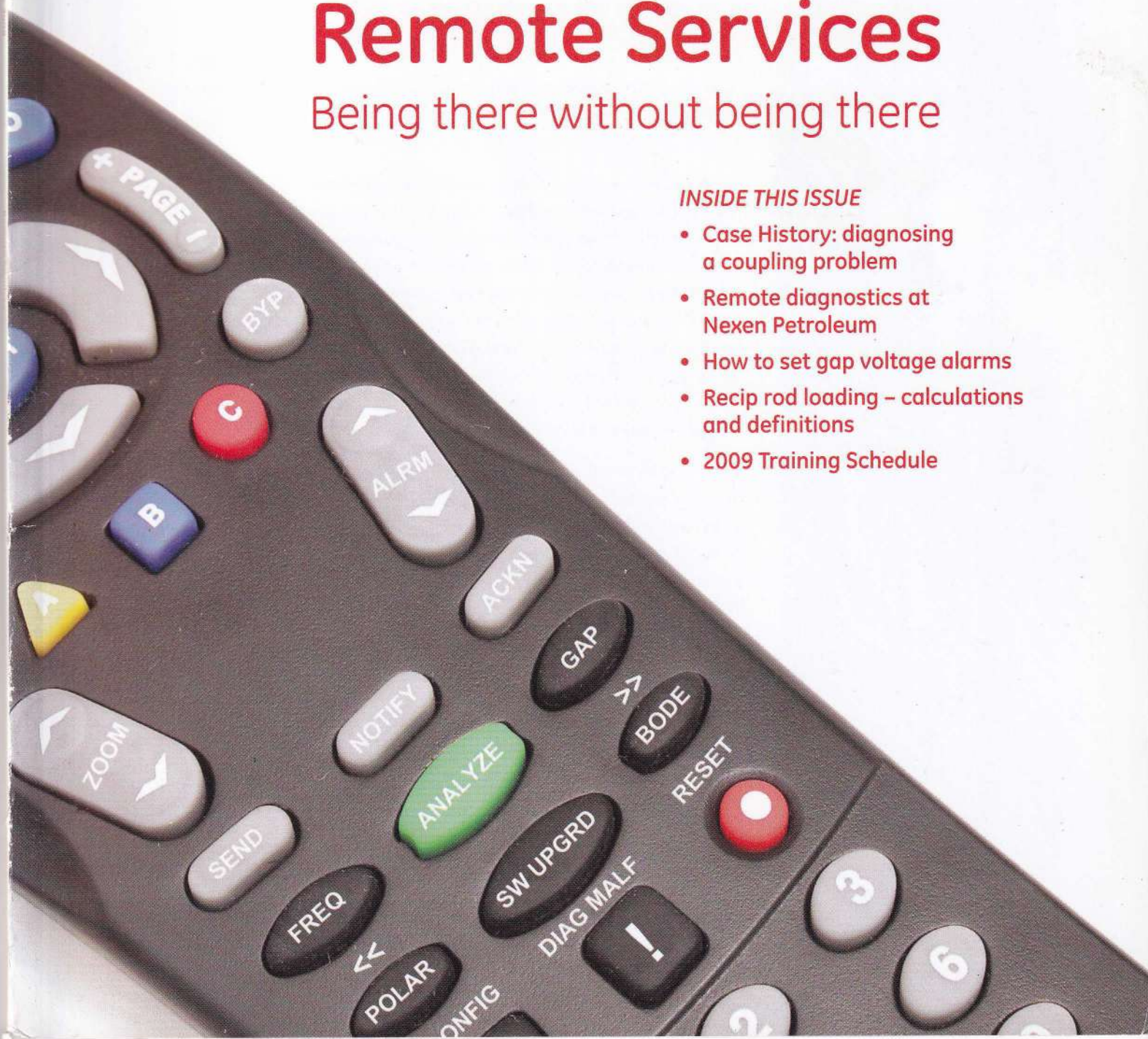
Volume 28 • Number 1 • 2008

Remote Services

Being there without being there

INSIDE THIS ISSUE

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- Remote diagnostics at Nexen Petroleum
- How to set gap voltage alarms
- Recip rod loading – calculations and definitions
- 2009 Training Schedule



Orbit

A Technical Publication for Advancing
the Practice of Operating Asset Condition
Monitoring, Diagnostics, and
Performance Optimization

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EDITOR'S NOTE

An Unprecedented Year

What a year 2008 has been. Who would have guessed that in the last 12 months...

- A barrel of oil would climb to more than 147 USD in June and then plunge to less than 35 USD as this issue of ORBIT goes to press.
- The credit markets in the United States would implode, triggering a world-wide financial crisis.
- Oil mavericks like T. Boone Pickens would be betting on wind as the next big "gusher" for energy.
- Every major automobile company would offer hybrid vehicles, and the waiting lists would reach all-time highs, only to subside again as gasoline prices plummeted.
- The USA would elect its first African-American president.

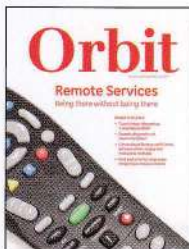
Indeed, it has been a year of unprecedented milestones and changes. However, one thing has remained unchanged through all of this: our customers' reliance upon their mechanical assets. Now, more than ever, wasted efficiency, unnecessary outages, unreliable assets, and ineffective maintenance practices cannot be tolerated as energy price extremes at both ends of the spectrum result in increased scrutiny on plant assets. For our customers who produce energy, high prices mean production can't be interrupted—even for a moment. Low prices, on the other hand, strain budgets already so lean that they can barely cover planned—yet alone unplanned—maintenance. For our energy-consuming customers, the pressures may be reversed, but exist nonetheless.

ORBIT magazine and the Bently Nevada* Asset Condition Monitoring products that it showcases exist to help you better manage your mechanical assets in good times and in bad. This issue, as always, features product application guidance, customer case histories, updates on new products, and much more. With a special focus on remote services and the inherent cost savings and quality improvements they offer, our cover story in this issue couldn't be more timely.

2009 promises to be a bumpy ride, just as 2008 has been. But regardless of what the future brings, one thing remains: we'll be right here to help you.



Steve Sabin – Editor



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- ▶ Keeping an Australian utility on-line with in-situ trim balancing
- ▶ Understanding recip valve temperature measurements

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New systems consisting entirely or partially of software automatically include a 1-year Platinum-level TSA. After the first year, you can renew your TSA at the Silver, Gold, or Platinum level. We believe that Platinum support provides significant value, and the majority of our customers will prefer to renew their TSA at this level. However, after the first year, regardless of whether you continue at a Platinum, Gold, or Silver level, you will be required to visit our online portal, or contact our technical support team, to validate your contact information and ensure the information we have on file is current and accurate. Information on how to access this new portal or contact our technical support staff via phone or e-mail is provided later in this article.

4. Enhanced Accessibility

Very few things are more frustrating than needing support and not being able to obtain it quickly. Let's face it: problems don't arrive pre-announced. When you need support, you usually need it now—not tomorrow and certainly not next week. To help deliver more timely

support, we are improving our service model and capabilities in the following ways:

- **Better local phone and e-mail support**

To provide you with timely answers in your own language, and in your own time zone, we are expanding our global technical support centers to four additional locations. Now, technical support expertise will be available at ten strategically situated locations designed to provide true 24/7 phone and e-mail support, no matter where you are located. A new "smart" phone system will ensure that a person, not a machine, will answer your call, and you'll even be given options to receive service in an alternate language if you speak multiple languages and do not need to wait for phone support in your primary language. You'll also be able to dial regional phone numbers rather than a single number in the United States. And, because every one of our ten global technical support centers will have access to the same system, pockets of expertise will no longer be isolated and customers will no longer have to choose between getting the expertise they need versus the language



they speak. They can have both. Our technical support capabilities will now encompass the following eight languages, and the list is continually growing:

- Arabic
- Chinese (Mandarin)
- Dutch
- English
- German
- Japanese
- Korean
- Spanish

• **New online support**

The quickest answers are at our customer's fingertips via an all-new technical support portal, www.bntechsupport.com. This self-help web site provides comprehensive resources such as the following:

- Submit technical questions and open cases
- Check the real-time status of your case
- View your case history
- Search for answers to issues that other TSA customers may have had

- Enter your contact information to have answers sent via e-mail directly to your inbox or mobile device
- Peruse and search your unique service knowledge repository
- Request copies of your site service reports online
- Download self-paced training on your purchased products

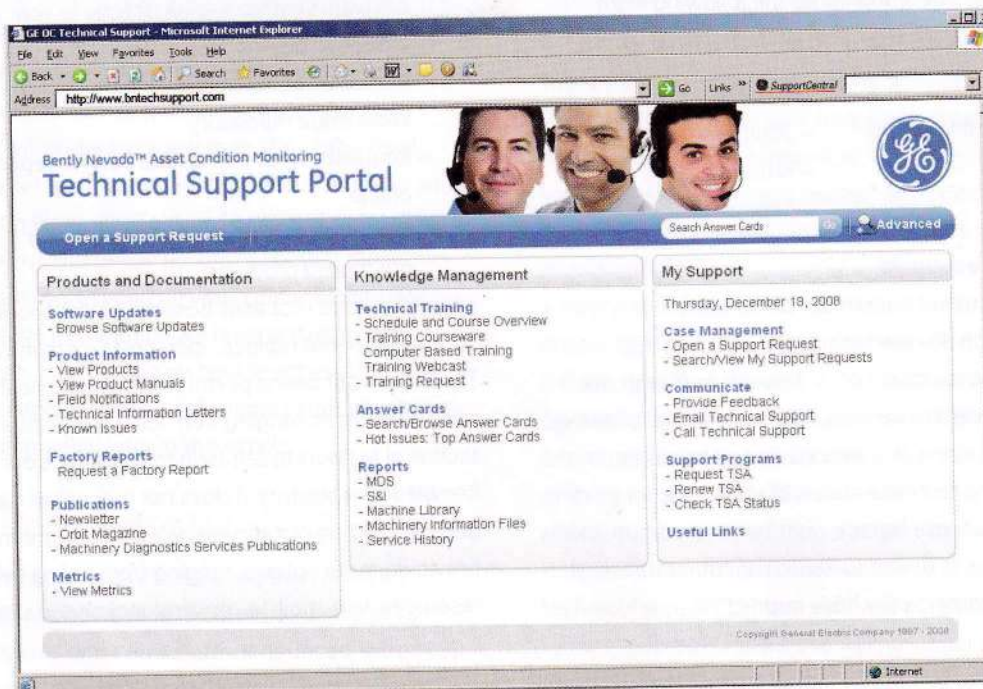
We understand that web-based systems should supplement—not replace—person-to-person contact. Thus, while our online portal will provide a host of online resources ranging from local phone numbers for technical support to self-help tools such as our service knowledge repository, it does not mean that we are depersonalizing our service delivery—we are merely providing more options, ranging from online self-help resources, to e-mail, to conventional phone support.

	Silver Support	Gold Support	Platinum Support
Online case management	✓	✓	✓
New product notification	✓	✓	✓
<i>Technical Connections</i> tips and best practices	✓	✓	✓
Product manual and firmware downloads	✓	✓	✓
Support coverage	Mon–Fri	24/7	24/7
Targeted max response time (priority)	6 hours*	4 hours	2 hours
System deployment repository		✓	✓
Factory test data report		✓	✓
Software upgrades		✓	✓
Online training		✓	✓
Technical support usage reports/audits		✓	✓
Priority involvement in beta program			✓
Service (S&I and MDS) report history			✓
Knowledge Library access			✓
Remote troubleshooting of software products**			✓
Disaster recovery assistance**			✓

*During work week. Next business day for requests outside normal business hours

**Installed by GE's Bently Nevada service team. High speed access required.

Three levels of TSAs are now available. Platinum Support is standard for the first year on all new systems containing software.



Our new online portal is specifically for customers with a Bently Nevada Technical Support Agreement.

- **Ongoing headquarters support**

While we strive to place the same level of expertise at each of our ten technical support call centers, customers always have the option of contacting our support team at corporate headquarters in Minden, Nevada. However, as previously noted, tools and capabilities previously available only to our headquarters technical support team have now been replaced with a global system that is accessible everywhere and by everyone. This effectively extends our corporate headquarters capabilities and expertise from just a single location to all ten locations.

- **Improved access to extended "subject matter expertise"**

We have always viewed outstanding customer support as a company-wide responsibility that touches every employee, not just those that carry a Technical Support title on their business cards. We understand that some questions require the involvement of people beyond our technical support staff, such as our design engineers or others with particular subject matter expertise. As always, TSA customers have access to the combined knowledge and experience of our entire organization. Our new support tools work company-wide to allow easier involvement in case resolution by those who may be outside the technical support department, ensuring we can deliver the right answers to your questions more quickly than ever.

TSAs – not just for emergencies anymore

A TSA obviously provides value when you have a problem. However, it also provides value when you don't have a problem by giving you access to numerous useful tools and archives. Combined, these capabilities make your TSA a valuable and inseparable part of your Bently Nevada system to deliver benefits such as:

- **Disaster recovery assistance** – enables the restoration of your system as quickly as possible in the unfortunate event of a computer crash or other IT-related problem.
- **Remote software troubleshooting and diagnostics** – helps get your system back into service quickly, often without the need to bring an engineer on site.
- **Access to software and firmware updates** – keeps your system current to ensure optimal performance.
- **New product notifications** – new additions to help your system deliver greater value.
- **Access to our online knowledge center** – a library of information and publications so you can get the complete answer when you need it.
- **Dedicated phone response** – gives you access to local support and global expertise.
- **Technical Connections** – online access to case studies and tips designed to help you improve system performance.
- **Online case management** – solving your problems is our priority. You can instantly see who is working on your case and view its progress.
- **Periodic technical support usage reports** – identify knowledge gaps and training needs for your staff.
- **Online training courses** – training can be delivered when needed...on your schedule; helps you develop new staff members more quickly.
- **Online service report history** – identify and understand recurring issues.

Don't lose it – use it

The truth is, you already have a TSA, but may not realize it. Every customer using non-obsolete hardware and/or software is entitled to technical support at a Silver level, but if more than 12 months have elapsed since initial activation, you need to go online (or contact your nearest GE sales professional specializing in Bently Nevada Asset Condition Monitoring) to either renew your TSA at a no-charge Silver level, or upgrade it to a Gold or Platinum level. You can also e-mail us at bntechsupport@ge.com

Taking excellent care of you

Our culture has always been one of "taking excellent care of our customers." The changes we have made to our TSA structure and delivery capabilities are simply the application of that culture at a practical level. We are making it easier to deliver the expertise and service you have come to expect from us during the more than five decades since we introduced the proximity probe and changed the way that machinery health is assessed.

We invite you to learn more about our TSAs and the recent improvements we have made to them by contacting your nearest sales professional, by visiting www.bntechsupport.com, or by sending an e-mail to bntechsupport@ge.com. 

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100 km northeast of Aberdeen, Scotland, Nexen Petroleum's Buzzard complex sits atop more than 550 million barrels of recoverable oil, representing one of the largest North Sea discoveries of the last decade.

Photo courtesy of Nexen, Inc. Used by permission.

Remote Machinery Diagnostic Services at Nexen Petroleum

Diagnosing a gas turbine problem from 800 km away

This case history describes how the authors, working remotely from a home office in The Netherlands and a corporate office near Aberdeen, Scotland, were able to connect to GE's System 1* condition monitoring software on a North Sea offshore platform complex, and remotely diagnose a problem with one of the platform's gas turbines. By isolating the root cause rapidly, the customer was able to take corrective actions while the impact was still relatively small and inexpensive.

Additionally, because the data analysis was done remotely, the issues associated with the normal logistics of getting an experienced machinery diagnostic engineer to the platform were eliminated altogether, along with attendant travel and per-diem costs.

Such remote diagnostic scenarios are becoming increasingly commonplace, and many of the limitations that previously constrained the effectiveness and practicality of performing machinery diagnostics remotely have been overcome. This article examines both the diagnostic methodology employed to isolate the root cause using the symptoms presented, and the various attributes of the remote system that were necessary to enable timely and accurate diagnostics from more than 800 km away.

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Nexen's Buzzard Platform

Nexen Inc. (www.nexeninc.com) is an independent, Canadian-based global energy company. It has offshore oil and gas interests and/or production facilities worldwide, including the North Sea, the Gulf of Mexico, and West Africa, as well as onshore in Western Canada, Colombia, and Yemen.

Nexen's Buzzard complex, the location of this case history, consists of three interconnected offshore platforms located approximately 100 kilometers northeast of Aberdeen, Scotland. When operating at peak production, it is designed to produce nearly 200,000 boe/d (barrels of oil equivalent per day) from a field with gross recoverable reserves of more than 550 million barrels. As such, it represents one of the largest North Sea discoveries of the last decade.

The Buzzard complex is operated by Nexen Petroleum U.K. Limited, a subsidiary of Nexen, Inc. Construction was completed in 2006, and the complex began producing oil in January 2007.

System Configuration and Maintenance Considerations

The ability to perform machinery diagnostics and proactive condition monitoring remotely is absolutely dependent upon the complete and correct configuration of the underlying system used to monitor the asset(s). This often means that more data must be available over a secure network than when one has the luxury of being on-site and merely walking a few steps to obtain the supplementary information needed. This might range from going out to the machine train to gather nameplate data or read a gauge, picking up a hardcopy of the machine's detail drawings or manuals, or sitting down with control room operators to ask a question about the sequence of events during a unit trip, or to access a screen on the process historian or DCS.

Being off-site is not necessarily a disadvantage *provided* the remote analyst is using a system in which everything he needs has been configured properly and completely, and appropriate access permissions

granted. Such configuration details, for example, might include bearing types, bearing clearances, shaft diameters, number of blades per stage, machine load, lube oil composition, turbine exhaust gas temperature sensor locations, ambient temperature and humidity data, etc. Necessary access permissions might be to items such as operation and maintenance manuals for the machines, maintenance logs, cross-sectional drawings of machine components and assemblies, and other pertinent documents. They might also include the ability to remotely view process conditions, such as from the DCS or historian. In most cases, these items are readily available. However, they merit special mention here not because access to such data and documentation is only necessary when one is working remotely; on the contrary, this data is almost always required whether one is performing machinery diagnostics on-site or remotely. They are mentioned here because when the analyst is remote, the option of simply walking over and accessing

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a hardcopy or reading a meter is obviously out of the question. Even picking up the phone to ask a question may be problematic, due to time zones if the analyst is on one side of the world and the machine is on the other.

To enable this required level of system configuration and maintenance, Nexen has a Supporting Services Agreement (SSA) whereby GE's Bently Nevada* Asset Condition Management team provides continual support for the health and proper operation of Nexen's 3500 series monitoring hardware and System 1 software. It is also noteworthy that several aspects of the SSA are actually delivered remotely, such as server maintenance, software upgrades, configuration, etc.

However, whether such "system maintenance" services are delivered remotely or in person, it is precisely because Nexen has such an SSA in place to maintain the health and configuration of their *instrumentation* that the authors were able to determine the health of the *machine*. In addition, Nexen personnel were able to accept the authors' recommendations with a high degree of confidence. They knew that the data upon which they were relying to make decisions was accurate and complete because the underlying instrumentation was regularly being maintained, configured, and updated as operating conditions changed.

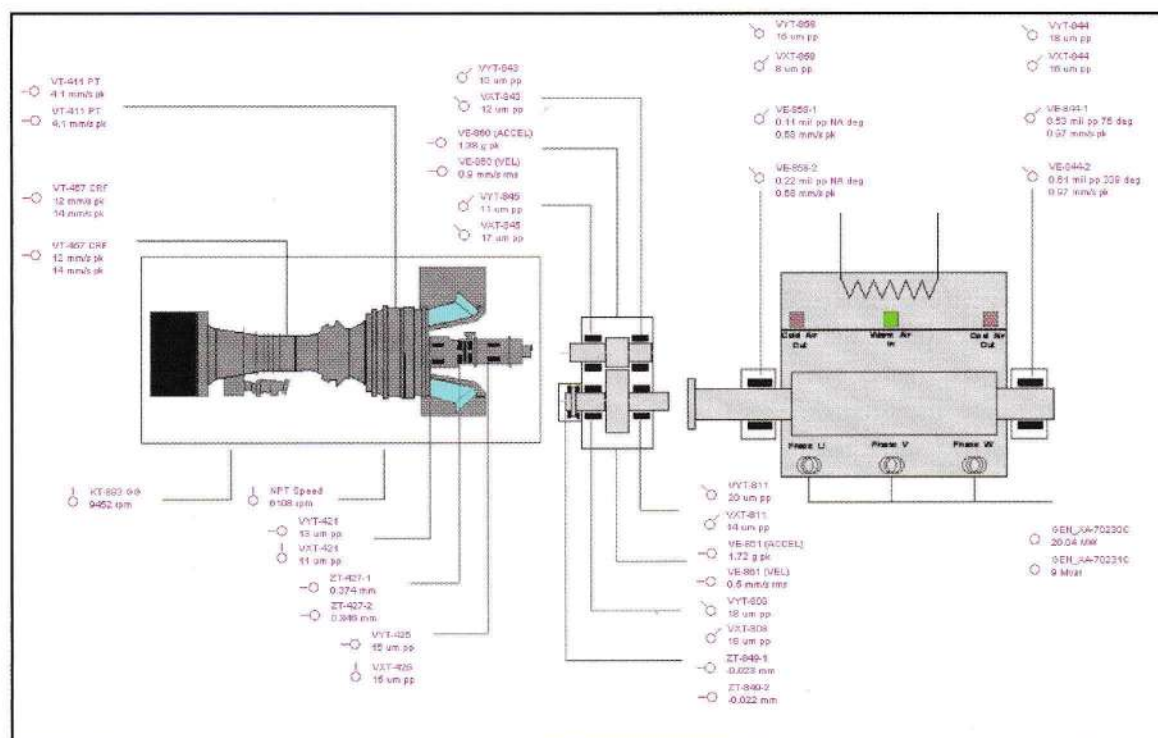


Figure 1. Unit C's machine train diagram from System 1 software.

Case History

Unit C is one of three critical gas turbines (A, B, and C) installed to generate the platform's electricity. Figure 1 shows a System 1 screen capture of the machine train and its corresponding vibration transducer arrangement. As can be seen, the gas turbine drives an electrical generator via a speed-reducing gearbox. Shortly after the Buzzard complex went into production, Unit C tripped unexpectedly due to power interruptions with the control systems.

Had it not been for the online condition monitoring system coupled with remote accessibility to this system by machinery diagnostics engineers, an underlying problem with Unit C's control logic that switched between the AC and DC lube oil pumps would have gone undiscovered until much later, as detailed next.

January 5, 2007

Unit C was started, ramped up to normal operating speed, synchronized, and loaded to 2 MW. After several hours, operators increased the load to 5.5 MW and left the unit running at steady-state conditions overnight.

January 6, 2007

At 8:57 AM, Unit C tripped unexpectedly. Careful sequence-of-events analysis showed that this trip was due to a node failure in the DCS. The DCS node failure interrupted power to the turbine control system, including the fuel gas detection subsystem. This system "fails safe" by tripping the turbine when it encounters a loss-of-signal—even momentarily—for any reason.

As mentioned previously, Unit C has two lube oil pumps. One is designed to run on primary AC power. The other is a back-up system designed to run on DC power from batteries in the platform's Uninterruptible Power Supply (UPS). This DC pump provides minimal lube oil should the AC pump fail for any reason, preventing the turbine from significant damage. When the turbine tripped, operators consulted the motor current indication in the main switch room. It showed that the DC Minimum Lube Pump had kicked in and was operational.

Confident that the trip was not due to mechanical problems with the turbine, and that the lube pumps had switched over seamlessly as designed to prevent any damage to the turbine, operators began the process of resetting the various instrumentation systems and start-up permissives. At approximately 10:10 AM, the first re-start attempt was made. Unfortunately, the gas detection system had not been reset and the turbine control system automatically aborted the start-up as a result. After resetting the gas detection system, a successful start-up ensued at approximately 10:29 AM. The unit was brought up to normal operating speed and then incrementally loaded as shown in Table 1.

Time	Load
11:00 – 13:00	3.0 MW
13:00 – 18:00	5.5 MW
18:00 – 07:41	11.0 MW

Table 1. Gas Turbine Loading Profile

January 7, 2007

At 07:41 and a load of 11 MW (refer to Table 1), Unit C again tripped suddenly following a trip from the Plant Shutdown (PSD) system. Operators once again confirmed that the DC Minimum Lube Oil Pump was running during shutdown, and less than two hours later, Unit C was restarted successfully and the load brought up to 4.0 MW. With the load remaining fairly constant, the unit ran for approximately two hours until 19:59 when yet another trip from the PSD brought the turbine down.

Rather than restarting the unit at this juncture, Nexen operators reviewed selected turbine data and noticed that excessive bearing temperatures had been present at bearing #1 (non-drive end of the gas turbine's power turbine) during the January 6th trip. Accordingly, they contacted GE's Bently Nevada Machinery Diagnostic Services (MDS) team for assistance in determining the severity and implications of these bearing temperature

anomalies. Nexen's SSA includes maintenance of their Bently Nevada hardware and software, as noted previously. However, it also contains provisions for remote machinery diagnostic assistance when needed.

Figure 2 documents the behavior of selected critical parameters during the January 6th trip, including bearing temperatures, gap voltages, and rotor speed. As can be seen, the bearing temperatures do not start to rise until the speed of the unit has slowed to around 2400 rpm, or less than half its rated speed. Upon reaching this speed, however, a rapid and significant increase in bearing temperature occurred, rising from approximately 80° C to more than 210° C in a span of less than two minutes.

It was speculated that this sudden temperature increase could only be the result of one thing: a bearing rub. It was further speculated that the rub occurred during

only a portion of the coastdown because the oil pressure had decreased to the point that a hydrodynamic wedge formed by the oil film could no longer support the weight of the rotor. The result was rotor-to-bearing contact and a subsequent dramatic increase in bearing temperature due to the friction.

Noteworthy also in Figure 2 is the corresponding increase in gap volts seen in the vertical radial vibration probe (red trace), suggesting the removal of bearing material due to the contact between the rotating shaft and the stationary bearing pads. The increase in gap volts seen in the vertical direction indicates that the shaft was moving away from the probe; i.e., dropping in the bearing due to increased clearances. Comparison of archived gap voltage readings prior to the trip with those obtained after the trip revealed that the rotor was indeed sitting considerably lower in the bearing.

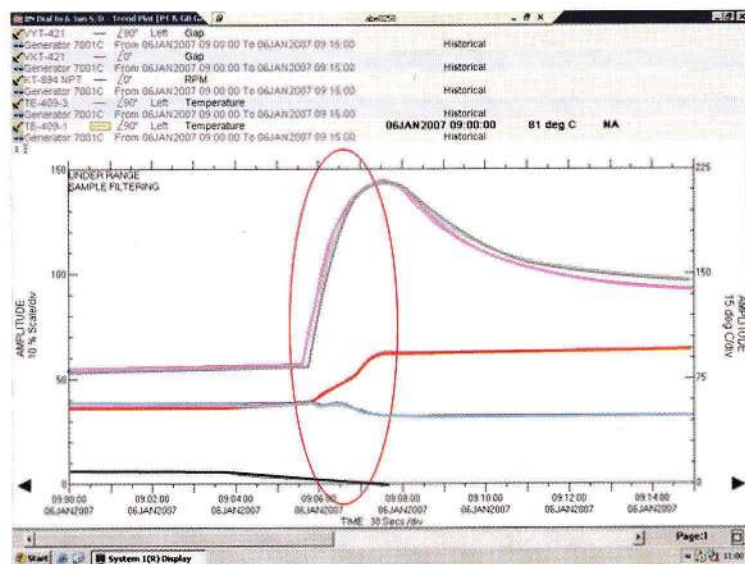


Figure 2. Fast trend plot (30 seconds per division) for Jan 6th trip of Unit C. Selected parameters from bearing #1 shown in this plot include bearing temperatures (pink/grey), radial vibration probe gap voltages (blue/red), and shaft rotational speed (black).

While several factors can cause changes in probe gap voltage, such as incorrect probe mounting allowing the probe to loosen and move away from the shaft, the correlation of increased bearing temperatures at the precise time that gap voltage changed made this extremely unlikely. As a result, a so-called "wiped bearing" seemed highly likely.

To further confirm the hypothesis that a bearing rub had occurred and that it was severe enough to remove babbitt material and increase the bearing clearances, additional data from Nexen's System 1 software was examined.

Archived data for a "normal" coastdown profile was first reviewed (Figure 3) and it showed the expected exponential decay of rotor speed. Total duration was approximately 21 minutes for the rotor to go from full speed to a complete stop, which is typical for this type of machinery configuration. This normal profile was then compared with the coastdown data from the January 6th trip (Figure 4). It was immediately evident that something was acting as a "brake" to more rapidly decelerate the rotor in just 4.5 minutes rather than 21 minutes. It was further evident that the coastdown was initially proceeding normally, but that something happened to change the deceleration rate at approximately 2400 rpm, as can be noted by the inflection point in the rpm data. At this moment, the "concave up" shape of the

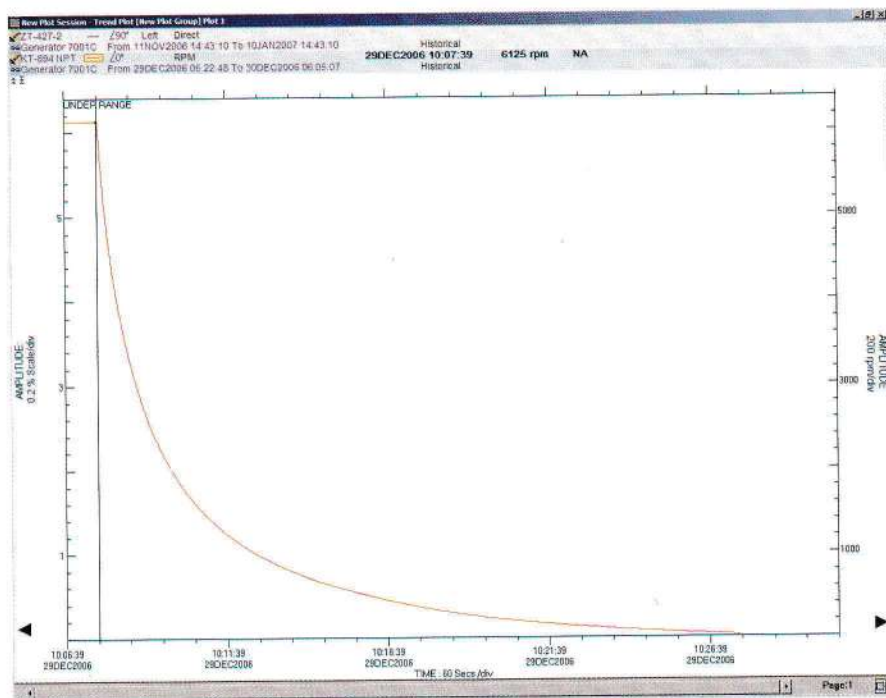


Figure 3. Trend plot of rpm during coastdown on 12/29/06 showing a normal exponential profile. Total coastdown time: 21 minutes.

curve changed to "concave down," indicating the rate of deceleration was increasing rather than decreasing, exactly as would be expected if a rub were occurring and higher frictional forces were being generated as the rotor slowed down in speed.

Combined, the unusual rotor deceleration, the elevated bearing temperatures, and the changes in probe gap voltages all strongly pointed to not just a wiped bearing, but the removal of enough babbitt material to warrant a physical inspection as bearing damage would likely be evident. Nexen was advised of these findings and agreed that a physical inspection was in order. As expected, a wiped bearing was found and indications were that it was due to a lack of lubrication.

Attention then turned to the lube oil system as the possible root cause. Inspection by Nexen's rotating machinery personnel onboard the platform revealed that the accumulator circuit for the oil system was not operating as intended, and oil pressure was not being maintained between a trip of the AC oil pump and subsequent start of the DC oil pump. Thus, although the DC pump had been operational as noted by operators observing the pump's motor current indicator, the actual lube oil pressure had not been adequate during the switchover. Appropriate corrective actions were taken to reconfigure the logic in the control system, ensuring that oil pressure would be maintained. The unit was returned to service without further incident.

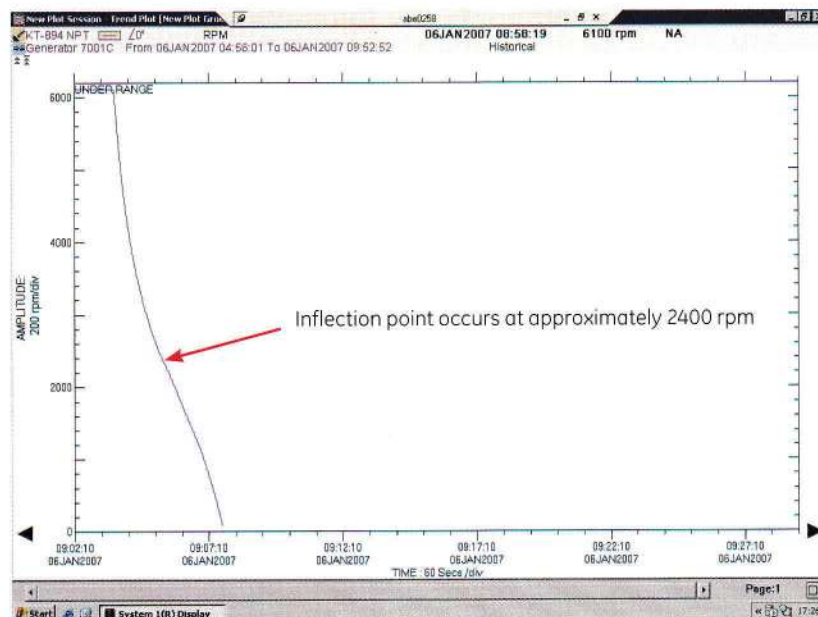


Figure 4. Trend plot of rpm during coastdown on 1/06/07 showing abnormal profile. Total coastdown time: 4.5 minutes.

Conclusions

The ability to rapidly diagnose this problem was in large part due to remote connectivity to Nexen's system by an experienced machinery diagnostics engineer. This eliminated the inherent delays and expense in traveling to an offshore platform. However, remote diagnostics would not have been possible without an underlying system that was being continually maintained properly to ensure the configuration was correct and complete, and that all necessary supplementary data, such as process conditions, design bearing clearances, archived "baseline" data, etc., were available and accessible remotely. In Nexen's case, they chose to use a Supporting Services Agreement to ensure the accuracy and availability of their system. As a result, when they needed to rely on the data supplied by the system and interpreted by machinery specialists such as the authors, they were able to do so with a high degree of confidence.

The root cause in this instance was the insufficient supply of lubricating oil during upset conditions. Even though a backup DC pump was provided and working, the control system logic that transitioned from the AC pump to the DC pump during a power failure did not allow the accumulator circuit to maintain the necessary oil pressure. Nexen wisely reviewed all of their rotating machinery and associated auxiliaries/controls to ensure that an uninterrupted supply of lubricating oil would be present on all bearings even under power loss situations, thus avoiding the possibility of a similar occurrence on another machine.

Had the machine continued to run with a wiped bearing, extensive collateral damage could have occurred. Worse, without accurate data showing the exact time that the bearing wipe had occurred, it would have been very unlikely that the root cause would have been traced to the lube oil system's control logic. As a result, switching between the AC and DC lube oil pumps would have resulted in continued wiped bearings. **□**

* denotes the trademarks or registered trademarks of Bently Nevada, LLC, a General Electric company.

Gap Voltage Alarms

While System 1 software, and even the underlying 3500 series machinery protection system, can be used to establish gap voltage alarms and thus indicate problems such as increased bearing clearances due to a wipe or electrostatic discharge, they are inherently reactive in nature. Trending of gap voltage is recommended in addition to hardware and software alarms as it may allow more subtle changes to be noticed. Also, establishing alarms in the software that are tighter than those in the underlying machinery protection system is recommended as they can provide multiple levels of warning regarding developing problems.

For more information on setting gap alarms, refer to page 70 in this issue of ORBIT for the article "Optimizing Gap Alarm Settings."

THREE NEW CUSTOMER APPLICATION CENTERS *opening in early 2009*

We are pleased to announce the opening of three additional Customer Application Centers (CACs) in early 2009. CACs are located in principal industrial centers around the world and feature permanent demonstration facilities where you can receive hands-on access to Bently Nevada* Asset Condition Monitoring products, GE's plant and machinery controls, and other products from our portfolio of optimization and control solutions. Each CAC is staffed with knowledgeable professionals that understand our products and the customers we serve.



MOSCOW, RUSSIA

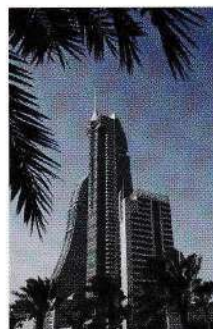
Slated to open in First Quarter 2009, the new Moscow, Russia facility is designed to complement our European CACs in Florence, Italy and Budapest, Hungary (see below) with a facility specifically for Eastern European customers.



BUDAPEST, HUNGARY

Also slated to open in First Quarter 2009, is the Budapest, Hungary CAC. Budapest is a major manufacturing center for projects outside the Americas, where our systems are placed in pre-wired cabinets, configured, and tested. It is an ideal location

for a CAC as many customers visit our Hungary facility each year to witness Factory Acceptance Testing on the systems they order.



MANAMA, BAHRAIN

Customers in Africa, India, and the Middle East will now have a CAC centrally located to meet their needs. In this large and growing region, Bahrain is a center of trade and technology, ideally situated to serve our customers. This new CAC is slated to open in First Quarter, 2009

REGION	LOCATION	STATUS
North America	Houston, Texas	OPEN
Asia	Singapore	OPEN
China	Shanghai, China	OPEN
Western Europe	Florence, Italy	OPEN
Central Europe	Budapest, Hungary	Opening First Quarter 2009
Eastern Europe	Moscow, Russia	Opening First Quarter 2009
Africa, India, Middle East	Manama, Bahrain	Opening First Quarter 2009
Latin America	Campinas, Brazil	Scheduled late 2009

To obtain specific contact information for the CAC director at each location, e-mail us at orbit@ge.com

* denotes the trademarks or registered trademarks of Bently Nevada, LLC, a General Electric company.

Call for Papers/ Save the Date

2009 European Users' Conference
26–28 May | Florence, Italy

Building on similar highly successful events in Amsterdam (2007) and Warsaw (2008), we are pleased to announce our 2009 European Users' Conference at the GE Learning Center in Florence, Italy.

TOPICS

Users of GE's Bently Nevada* Asset Condition Monitoring products such as ADRE*, 3500 Series Machinery Protection Systems, and System 1* software, or GE's turbine and plant control products such as the OC6000e and Mark* Vle, are invited to submit papers on how they are using these products to optimize, manage, and control their assets. Particular preference will be given to papers that address one or more of the following topics:

- Justifying a condition monitoring program to management and documenting actual versus expected benefits achieved
- Integration of our products to other control, condition monitoring, and automation platforms such as Computerized Maintenance Management Systems, Distributed Control Systems, Plant Historians, Turbine/Machinery Controls, oil analysis software, thermography software, etc.
- Machinery diagnostic case histories

Other 2009 Regional Users' Conferences include:

- China: Beijing – May
- Asia: Bangkok, Thailand – Third Quarter
- Middle East: Gulf Region – Third Quarter

- Turbine or plant control case histories showcasing innovative control applications, integration, or optimization
- Early adoption experiences with new products, such as remote machinery diagnostics or wireless condition monitoring

SUBMITTAL FORMAT

- 200-word abstract
- Adobe Acrobat (PDF), Microsoft WORD (.doc), or plain text (.txt)

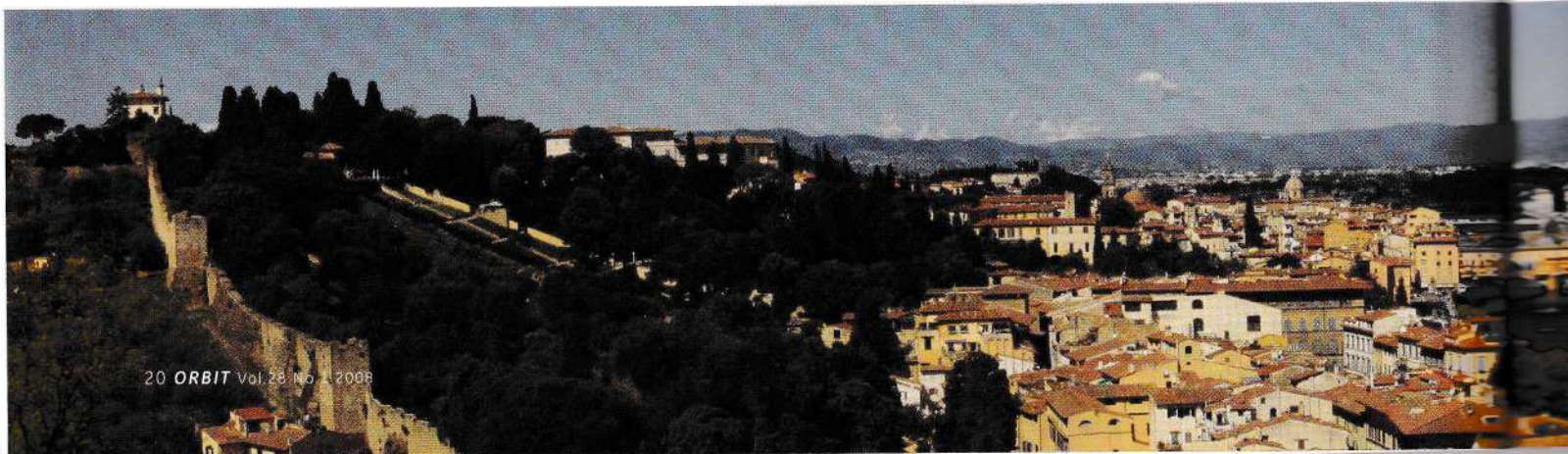
SUBMITTAL DEADLINES

Abstracts must be received no later than 15 February 2009 by submitting to peter.lugtenburg@ge.com

If accepted for presentation, final papers are due no later than 31 March 2009.

VENUE

Florence is a treasure of history, architecture, art, and culture. It is deemed by Yahoo! Travel as "...one of the most glorious cities in the world," and by Wikipedia as the "...cradle of the Renaissance for its monuments, churches, and buildings." The Historic Centre of Florence was declared a World Heritage Site by UNESCO in 1982.



CONFERENCE TRACKS

Our 2009 conference will again feature separate tracks for controls and condition monitoring.

PRELIMINARY AGENDA

Monday 25 May 2009

8:00 – 17:00 Optional 1-day Introduction to Machinery Diagnostics (condensed version of our popular 5-day in-depth course)

Tuesday 26 May 2009

9:00 – 11:00 Optional pre-conference tour of GE Oil & Gas Florence Manufacturing Facility
12:00 – 13:00 Opening Luncheon with Keynote Speaker
13:00 – 17:00 Conference Tracks
18:00 – 21:00 Group Dinner at top floor Grand Hotel Minerva

Wednesday 27 May 2009

8:00 – 17:00 Conference Tracks
18:00 – 21:00 Product Fair at Customer Application Center (inside the GE Learning Center)

Thursday 28 May 2009

8:00 – 12:00 Conference Tracks
12:00 Conference End
13:00 – 15:00 Optional post-conference tour of GE Oil & Gas Florence Manufacturing Facility

REGISTRATION

Visit www.ge-energy.com/unlock and follow the links for the 2009 Florence, Italy conference.

CONFERENCE FEE

- **Earlybird:** 200 Euros prior to 28 Feb 2009
- **Regular:** 300 Euros after 28 Feb 2009

- **Multiple Attendee Discount:** Multiple attendees from the same company will each receive a 30% discount.

Conference fee includes lunches and continental breakfasts Mon–Thurs, and Group Dinner on Tuesday.

Participants are responsible for any additional meals, their own lodging, and all travel-related costs.

SPOUSE PROGRAM

Subject to demand, special tourist activities for spouses may be organized. Please indicate your interest at time of registration by visiting www.ge-energy.com/unlock.

PLANT TOUR

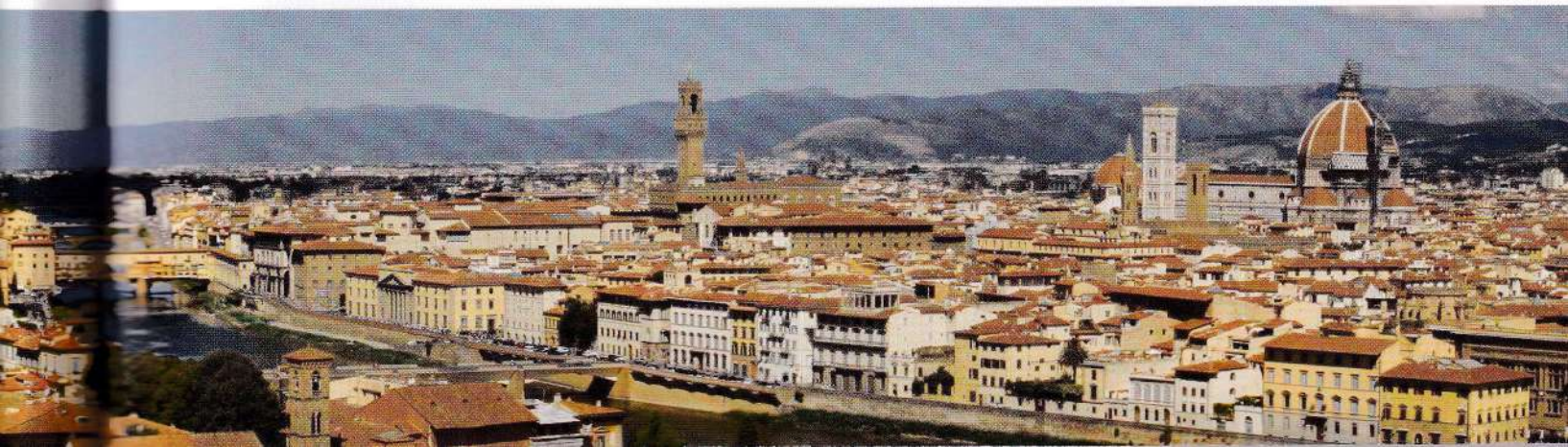
With sufficient customer interest, upon conference closure on Thursday afternoon, plant tours of the GE manufacturing facility may be arranged.

HOTELS

The official host hotel for the conference is HILTON GARDEN INN, Florence Novoli. A block of rooms has been reserved until 30 April 2009 at the discounted conference rate of 105 EUR (single occupancy). The SOFITEL Firenze is the selection for those who want to stay in the center of town. A block of rooms has been reserved until 30 April 2009 at the discounted rate of 144 EUR (single occupancy). Please mention "GE User Days" when booking your room prior to 30 April to obtain this special discount. Additional hotels are available by contacting your travel agent or via online travel sites such as travelocity.com, hotels.com, expedia.com, and many others.

Attendees are responsible for making their own hotel arrangements.

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System 1* Software version 6.5

Simpler to use, simpler to install, simpler to maintain – yet more powerful

Following its release in 2001, System 1 software is today installed at thousands of locations worldwide, ranging from a single server used with a portable data collector, to enterprise-wide solutions on different continents with dozens of servers linked remotely via the customer's corporate data network.

From the outset, our goal with System 1 software has been to deliver a unified platform and user interface, providing you with a single window into the condition of every asset in your enterprise, regardless of whether online or offline data sources are used. To accomplish that, the software has grown from its initial support for manual route-based data collection instruments to include our online machinery protection systems such as 3500, 3300, and 1701; our Trendmaster* "sensor-bus" architecture for online intermittent condition monitoring on essential assets; various interfaces to process control and automation systems for importation/exportation of key parameters and statuses; manual data entry of notes, and links to

pertinent asset documentation such as manuals, drawings, and maintenance logs; engineered interfaces to popular CMMS systems such as Maximo™ and SAP®; and, most recently, full support for our Essential Insight.mesh* wireless condition monitoring architecture.

[Editor's Note: The Volume 29, Number 1, 2009 issue of ORBIT will provide extensive details on this new wireless offering and its capabilities.]

System 1 today delivers the level of integration between online and offline systems that we originally envisioned. However, it is an ongoing journey as we continually enhance the product, based on your feedback and the feedback of our own service personnel, who increasingly use System 1 software to remotely diagnose machinery. With the release of version 6.5, we have introduced a multitude of enhancements. While they have made the software more powerful, they have also addressed something even more important: they have made the software easier to use, easier to install, and easier to maintain.

The enhancements can be grouped into five major categories as summarized in the remainder of this article.

Scott Roby – Product Line Manager – System 1 Software – Bently Nevada Asset Condition Monitoring –
GE Energy – scott.robby@ge.com



1. SIMPLIFIED USER EXPERIENCE

We've made System 1 software easier to use...

User Profile Management

- ❑ Dramatically simplifies the User Experience
- ❑ For a given user, or class of users, you can remove complexity from System 1 Display
- ❑ Turn off panes, menu options, and controls that are not needed
- ❑ Select which plots the user will need
- ❑ Select which hierarchies to view
- ❑ Control the severity of event notifications – allowing operators to only see high severity alarms
- ❑ Control the severity of instrumentation alarms (e.g., NOT OK, NO DATA, etc.)

Asset Health Visibility

- ❑ Active Alarm Manager – Helps users focus on what is currently in alarm
- ❑ Latching Software Alarms – reduces nuisance alarms
- ❑ Disable Alarms – useful when performing system or machine maintenance
- ❑ Hierarchy Annunciation – reserved for hardware and software alarms (NO DATA / NOT OK only drive an icon in the hierarchy but do not flash)
- ❑ Hierarchy Navigation – graphical view “back button”
- ❑ Hierarchy Simplification – partitioning supported to hide non-pertinent parts of the enterprise for a user
- ❑ Transient Status Indicator – visual indicator when a train or collection group is in transient data collection mode
- ❑ Simplified Actionable Information* – improves the “So What?” factor for operators and machinery diagnostic engineers through clean action text and clear details text; improves the “Show Me” factor for machinery diagnostic engineers by presenting the supporting evidence that directly ties to the alarm and allowing easy launch of relevant plots from the supporting evidence

Data Analytics

- ❑ Pause and Replay on Current Value Plots – temporarily stop the data stream to dig into the data for deeper analytics
- ❑ Mixed Mode Current Value Trend Plots – now with 20-minute historical data back-fill

- ❑ Intelligent Plot Defaults – save time spent in most obvious configuration of plots (e.g. “Show Set Points,” etc.)
- ❑ Plus Spectrum – can now be launched from waterfall or cascade plots
- ❑ Preserve Plot Settings – maintains last configured type and settings
- ❑ Horizontal Tile of System 1 Plots
- ❑ Smart Plot Launch – double-click on alarms to launch a pre-configured set of plots
- ❑ Bargraph Timestamp – last updated timestamp now in bargraph window
- ❑ Signal Integration – vibration signals can be numerically integrated (such as velocity to displacement) on the fly for viewing/analysis, or permanently for inclusion in the historical database

Display Client Improvements

- ❑ Display Client Auto-Reconnect – if the DAQ server is not available when display tries to connect it will simply retry until DAQ is available; once Display makes a connection, it populates hierarchy status, current alarms, and makes current values available
- ❑ Display Client Configuration Change Reconciliation – if the configuration changes, Display will automatically reconcile those changes so that a disconnect and reconnect is no longer required
- ❑ Graphical View Printing – captures and prints the graphical view through a simple right-click menu option

2. SIMPLIFIED INSTALLATION AND CONFIGURATION

We've made System 1 software easier to install and configure...

Faster Installation and Initial Setup

- ❑ Turbo-charged installation – totally overhauled to be very fast, very easy
- ❑ Pre-Requisites Install – execute with minimal user interaction (~ 10 minutes)
- ❑ Installation Package Options – Client Install, Server Install, Install Everything, or Advanced Install
- ❑ Select System 1 Administrator account – not necessarily System1Admin, can be domain account
- ❑ Stand Alone Enterprise Setup – covers 80% of all usage scenarios where all System 1 Server components are installed on one computer; a wizard walks you through getting the server set up; loads System 1 software to the point where you are ready to start configuration in about 20–30 minutes, including enterprise activation through Bently Nevada* technical support
- ❑ Intelligent Upgrades – an additional feature in Stand Alone Enterprise Setup that automatically translates all the legacy licenses to v6.x format when upgrading a single DAQ / System 1 installation with pre-v6 software

Easier Configuration

- ❑ Data Manager* 2000 (DM2000) Importer – automatic importing of configuration settings and archived data from legacy DM2000 systems such as 3300 or 3500 racks with TDXnet, or 1701 series systems with an FMIM module; reduces configuration time from days to approximately two hours and can include process data, not just vibration data
- ❑ System 1 on Workstation Computer – ideal for smaller DM2000 installations (up to 5 Racks and 500 total points)



- ❑ Intelligent 3500 Rack Import – for rotating assets; quickly get to a point of collecting dynamic and transient data from 3500 racks without having to reconfigure settings already available from the 3500 rack that can be “passed through”
 - Automatically configure probe pairs
 - Automatically configure waveforms
 - Automatically configure Collection Group (Transient Parameters)
- ❑ Auto-Archiving – schedule periodic automated archiving to regularly back up data without user intervention
- ❑ Reference Data Management – improved and simplified tool for managing reference data, all in one dialog; can capture “Reference Samples” and “Reference Sets” to preserve a data set of interest for future reference
- ❑ RulePak Deployment – improved ability to deploy user-written rules across a plant or enterprise
- ❑ Improved Mechanical RulePaks – improved Actionable Information and supporting evidence details
- ❑ Configuration Preferences – similar in concept to User Profiles for the Display Client, configuration preferences can be used to turn off the features and tools that are not needed, dramatically simplifying the use of the Configuration Client

3. IMPROVED SCALABILITY

We've made System 1 software more scalable...

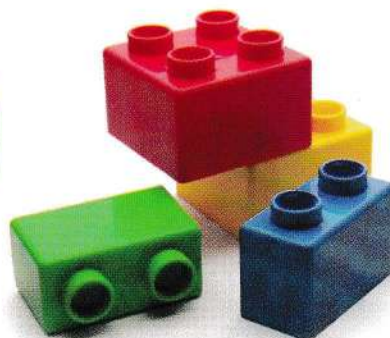
Application Scalability

- ❑ System 1 Enterprise edition now runs on a workstation PC – an IT-friendly PC (non-server computer or OS) for small applications:
 - Up to 5 Racks, 50 DSMs, 500 total points
 - Can include Decision Support* Studio for custom rules
 - Uses SQL Standard Edition, supports high-resolution and/or long-term data storage and large historical databases
- ❑ Available Multi-Server Solution – can scale to monitor a large number of assets with a distributed architecture
 - Multi-DAQ enterprises
 - Distributed Database Server Architecture
 - Decision Support RulePaks

Enhanced Microsoft SQL Server Support

- ❑ Microsoft® SQL Server Professional Edition – best-in-class database engine; used for System 1 server applications
- ❑ Microsoft® SQL Server Standard Edition – standard database engine; used for System 1 workstation applications

- ❑ Microsoft SQL Server Express Edition – embedded database engine with 4GB size limit; used for small applications (e.g., portable data collection only)
- ❑ Microsoft SQL 2000 – support for legacy SQL software
- ❑ Microsoft SQL 2005 – preferred for all System 1 applications
- ❑ SMC Database Management Module – a powerful tool to manage the allocation of storage space; addresses the requirement imposed by many customers to store at least one year of data for all assets in their System 1 database



4. IMPROVED MIGRATION CAPABILITIES

We've made it easier to upgrade to the latest version of System 1 from Data Manager 2000 software and previous versions of System 1 software...

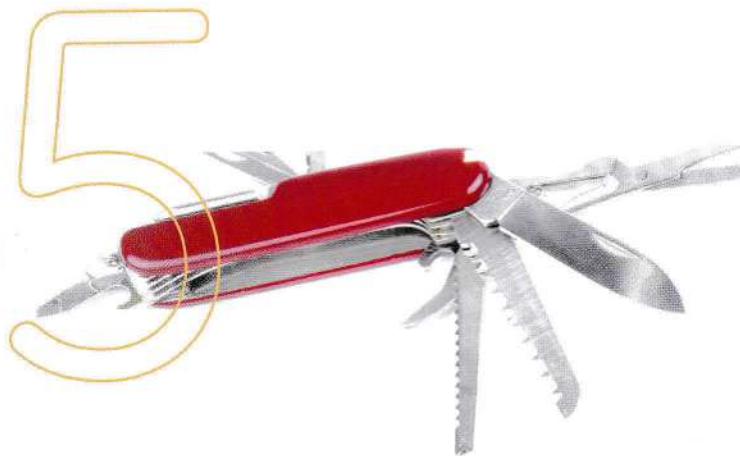
- ❑ Commercial DM2000 Upgrade Package – includes the required software licenses, the software tools for importing DM2000 configuration files and historical data to System 1, the necessary onsite services, and four hours of onsite training
- ❑ Merge existing DM2000 into existing System 1 – DM2000 backups and archives can be imported into a System 1 format and appended to an existing and active System 1 archive; allows users to "stitch together" data files
- ❑ Combine multiple DM2000 systems into one System 1 enterprise – multiple small DM2000 systems can be migrated into a single System 1 enterprise; a single System 1 enterprise can accommodate up to 10 DM2000 systems

- ❑ "Best of" Data Manager / Trendmaster software features now included in System 1
 - Flashing Toolbar and Taskbar
 - Transient Condition Indicator
- ❑ Easy upgrade path and license translation for legacy System 1 (v3, v4, v5) installations – migrate to System 1 v6.5 in less time due to an expedited license process



5. APPLICATION IMPROVEMENTS

We've made System 1 software more capable and powerful, with support for more applications and integration requirements...



Enhanced Reciprocating Compressor Support

- ❑ Simplified Initial Configuration – 50% reduction in configuration time through the use of native asset properties that remove the need for custom attributes
- ❑ Improved Plot Configuration Tools – 50% reduction in the time required to configure recip plots and plot sessions
- ❑ Recip Compressor Crank Angle Overlay Plot – up to 16 curves (6 plots in 2 layers); first plot shows primary curves in foreground (usually 4-curve plot of cylinder pressure vs. crank angle); remaining 5 plots are secondary curves shown in background
- ❑ Recip Waterfall Plots – support for up to 7 different data sources
 - Pressure
 - Velocity
 - Rod Drop
 - Acceleration
 - Rod Position
 - Impulse
 - Hyper Rod Position

- ❑ 3500/70, /72, and /77 Monitor Auto-Configuration Propagation – numerous asset properties are configured in 3500 recip monitoring modules; when channels are associated to an asset, properties are automatically propagated which removes the need for duplicate configuration

Additional Application Improvements

- ❑ Support for Essential Insight.mesh* wireless system (uses service pack installed separately from System 1 version 6.5)
- ❑ System 1 and Yokogawa PRM™ Integration – exports System 1 hierarchy into PRM; passes asset and instrumentation data and events to PRM; allows hyperlinking from PRM assets to System 1 assets

To learn more about System 1 software version 6.5 and its specific features/functions, contact your local GE sales professional specializing in Bently Nevada* Asset Condition Monitoring, or visit us online at www.ge-energy.com/system1. 

* denotes the trademarks or registered trademarks of Bently Nevada, LLC, a General Electric company.

Save the Date

Advanced Machinery Dynamics Course

November 9-13, 2009 | Florence, Italy

May 18-22, 2009 | Houston, Texas

Hone your machinery diagnostic skills with our Advanced Machinery Dynamics course. In 2009, it will be offered in both Houston, Texas or Florence, Italy.

The course is designed to extend your knowledge of machinery diagnostic techniques and rotor dynamics as applied to rotating machinery. It is ideal for engineers involved in the design, acceptance testing, and maintenance of rotating machinery, post-graduate engineering students, and academic researchers and professors involved in rotor dynamics.

COURSE CONTENTS

- The use of synchronous and non-synchronous perturbation testing to evaluate complex Dynamic Stiffness in rotor/bearing/seal systems, including its modal parameters. You'll learn how to bring analytical model response predictions into closer agreement with actual machine data.
- How rotor torsional modes are coupled with lateral modes, and how that information may be used for early detection of shaft crack.
- How to model machinery operation and malfunctions in fundamental terms, preparing you to better identify and understand machinery problems in the field.

Learning is reinforced by putting theory into practice with hands-on workshops that use standard vibration diagnostic tools on machine-simulating rotor kits.

To further solidify your understanding, case histories that highlight the vibration documentation, analysis, and machine malfunction corrective techniques will be presented throughout the course.

REGISTRATION INFORMATION

The registration fee is 3000 EUR (excluding VAT) for Florence and 3000 USD for Houston. Each participant will receive a comprehensive course manual and reference book. The registration fee also includes continental breakfast and lunch each day, as well as one group dinner.

To register for the Florence course, contact Dr. Thomas Kafka, our European Training Manager at:

Phone: +49 6102 36 18 37

e-mail: thomas.kafka@ge.com

For the Houston course, contact Mark Sando, our Training Registrar at:

Phone: +1 775 215 1387

e-mail: mark.sando@ge.com

You may also visit www.ge-energy.com/training, click on "Equipment & Software Training" and follow the links to Bently Nevada Training, or call your nearest GE Energy sales representative specializing in Bently Nevada Asset Condition Monitoring products and services.

Rod Load Calculations and Definitions for Reciprocating Compressor Monitoring

The term "rod load" has been used for decades to describe the maximum forces a reciprocating compressor assembly can withstand. The term has some ambiguity, but recent papers have clarified some of the key definitions and terms [1].

With the improved understanding beginning to permeate industry, customers have begun to ask questions about how GE's Bently Nevada* 3500 Series Monitoring Systems and System 1* Condition Monitoring Software (referred to as 3500/S1 hereafter) calculate these values. The purpose of this article is to answer those questions.

Calculation Methodology

Figure 1 shows the rod load curves and data generated by 3500/S1.

Inertial Force

The red line in Figure 1 represents the forces due to inertia. The inertia mass for nearly all reciprocating compressor condition monitoring installations includes the crosshead assembly, crosshead nut, piston rod, and piston assembly.

This collection of mass for inertia is consistent with the definition provided in API-618 5th Edition (Data Sheets, Page 7, line 31)[2]. 3500/S1 does allow the user to exclude the crosshead mass from the inertia force calculations (see Figure 2); however, the configuration is rarely encountered in the field, is not consistent with API-618 4th or 5th edition terminology, and is outside the scope of this article.

Gas Force

The blue line in Figure 1 represents the gas forces acting on the compressor's static components and running gear. This force is the gas load referenced in API-618 (paragraph 6.6.2)[2]. To obtain this force, the indicated cylinder pressure on the head end is multiplied by the head end area of the piston. This is shown in green in Figure 3 for a typical double-acting cylinder. The resultant force is then subtracted from the indicated crank end cylinder pressure times the crank end piston area (shown in brown in Figure 3). This summation represents the net force [1] acting on the piston rod and can be written as:

$$F_{\text{GasLoad}} = (A_{\text{CrankEnd}} \times P_{\text{CrankEnd}}) - (A_{\text{HeadEnd}} \times P_{\text{HeadEnd}})$$

The cylinder pressure varies continuously throughout the revolution of the crankshaft, so the calculations must be performed multiple times throughout the revolution to obtain a curve. For each 360 degrees of crankshaft rotation, 3500/S1 collects 720 indicated cylinder pressure data points simultaneously for both the head and crank ends. The gas load calculation is thus performed 720 times for each revolution.

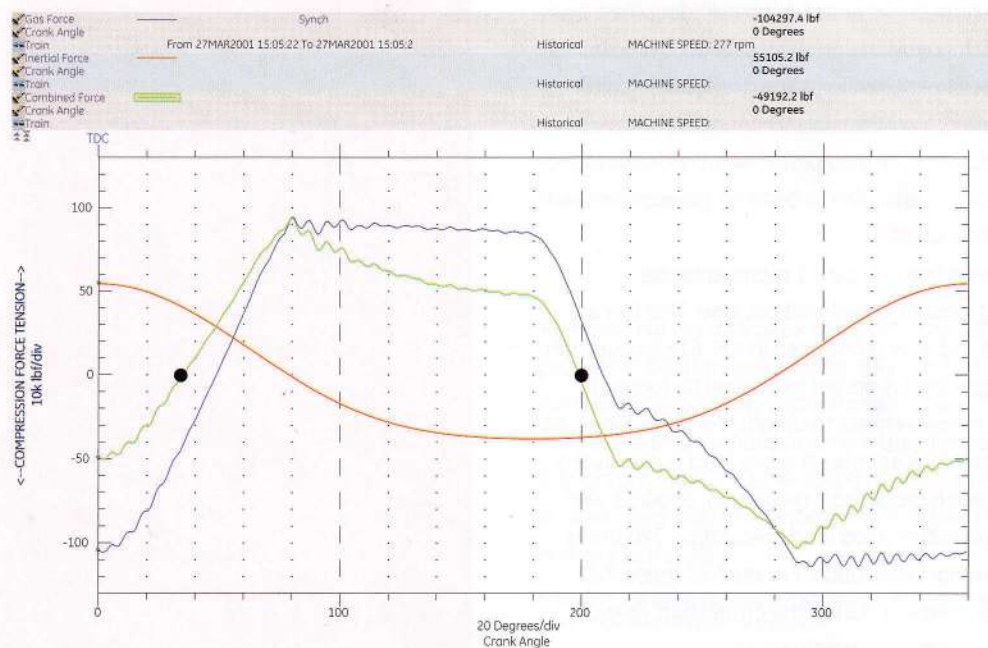


Figure 1. Rod load curves generated by 3500/S1.

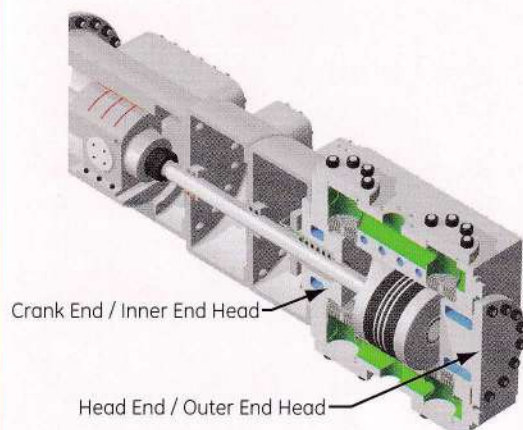


Figure 2. Reciprocating compressor terminology.

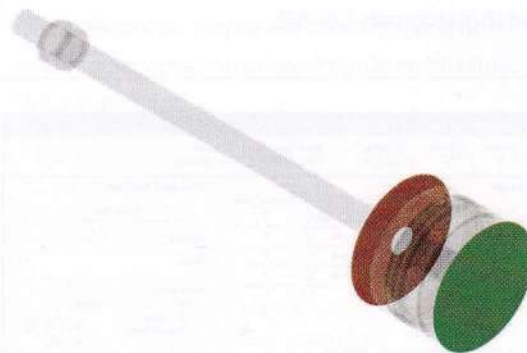


Figure 3. Piston areas used for gas rod load calculation.

The gas pressures in the chamber act not only on the piston, but also on the heads of each cylinder. The combined gas force on the crank and head end heads has the same absolute value as the gas load calculated above, but acts in the opposite direction (i.e., has opposite sign).

Combined Rod Load

Finally, the green line in Figure 1 represents the combined rod load, or crosshead pin load. This force is the combined rod load referenced in API-618 (paragraph 6.6.1)[2]. The gas load is added to the inertia force at each point of measurement to obtain this force. Since, as noted in the previous section, the gas load is computed 720 times for each crankshaft revolution, 3500/S1 also performs the combined rod load calculation 720 times for each crankshaft revolution. For each of these 720 points of measurement during the crankshaft revolution, the calculation can be written as:

$$F_{\text{CombinedRodLoad}} = F_{\text{GasLoad}} + F_{\text{Inertia}}$$

When the mass used in the inertia force calculation includes the crosshead, the smallest distance between the points of zero force (shown by black dots at approximately 35° and 200° of crank angle in Figure 1) represents the degrees of rod reversal referenced in API-618 (paragraph 6.6.4)[2].

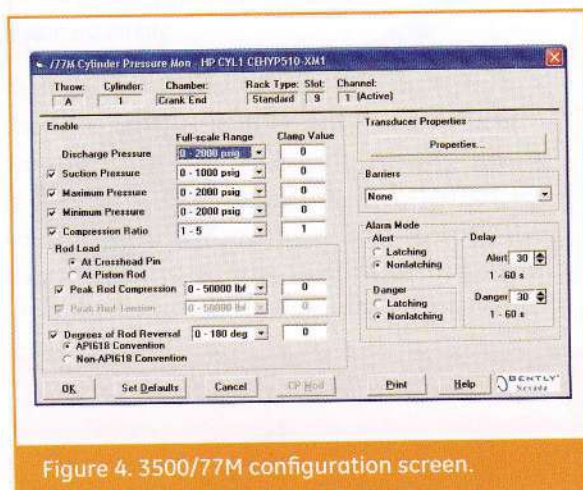


Figure 4. 3500/77M configuration screen.

Terms and Definitions

The following definitions draw extensively from reference [1]. The reader is encouraged to consult this reference for a complete discussion of these terms and others, as well as a valuable historical perspective.

- **Combined Rod Load:** *The sum of actual gas load (including valve and passage losses) plus inertia loads at the crosshead pin, in the direction of the piston rod.*

This is the force curve labeled "Combined Force" in System 1 software's rod load plots when the inertia force includes the mass of the crosshead assembly. This force varies continuously throughout the revolution. The term appeared in both the 4th and 5th editions of API-618 with the same definition; however, the 4th edition required that it be calculated every 10 degrees and the 5th edition required that it be calculated every 5 degrees. Reference 3.7 of API-618 5th edition for a formal definition.

- **Crosshead Pin Load:** *Same definition as "combined rod load."*

Note this term is not defined within API-618, but is a commonly encountered industry term used to clarify the component at which the combined rod load calculations are being done.

- **Gas Load:** *The force resulting from the internal pressure in each chamber acting on the associated piston and cylinder head surfaces.*

This is the curve labeled "Gas Force" in System 1 software plots. As it depends only on the pressure and cylinder geometry, it remains the same whether the force calculation is done at the crosshead pin or piston rod. The term appeared in both the 4th and 5th editions of API-618 with the same definition; however, 4th edition required

that it be calculated every 10 degrees and the 5th edition required that it be calculated every 5 degrees.

- **Maximum Allowable Continuous Combined Rod Load (MACCRL):** *A value determined by the OEM based on design limits of the various components in the compressor frame and the running gear (bearings, crankshaft, connecting rod, crosshead assembly, piston rod, piston assembly).*

With minor exceptions (see 6.6.5 of API-618, 5th edition), no single value of combined rod load can exceed the manufacturer's ratings for maximum allowable continuous combined rod load (see paragraph 3.19 of API-618 5th edition for a formal definition). OEMs may have individual limits for compressive rod load, tension rod load, and compressive plus tension.

- **Maximum Allowable Continuous Gas Load (MACGL):** *A value determined by the OEM based on the design limits of the static components (frame, distance piece, cylinder, and bolting).*

With minor exceptions (see 6.6.5 of API-618, 5th edition), no single value in the gas load curve can exceed the manufacturer's ratings for maximum allowable continuous gas load. Reference 3.20 of API-618 5th edition for a formal definition.

- **Rod Reversal:** *The shortest distance, measured in degrees of crank revolution, between each change in sign of force in the combined rod-loading curve.*

Reference paragraph 3.49 of API-618 5th edition for a formal definition; however, note that the API 618 definition is not entirely accurate as it references "piston rod loading" instead of "combined rod loading."

Had 3500/S1 been configured to calculate rod load at the piston rod, the inertia forces would no longer include the crosshead mass. The combination of this inertia force and gas force results in the forces that act on the piston rod, next to the crosshead. Note that this force no longer reflects those acting on the crosshead pin, and therefore cannot be used to calculate rod reversal.

Conclusion

Rod load curves and peak rod load/reversal values provide important insight into the health of a reciprocating compressor. Understanding how 3500/S1 calculates these values and how they relate to Original Equipment Manufacturer (OEM) and API-618 definitions enables end-users to better manage their reciprocating compressors. 

* denotes the trademarks or registered trademarks of Bentley Nevada, LLC, a General Electric company.

References

- [1] Atkins, K.E.; Hinchliff, M.; McCain, B., "A Discussion of the Various Loads Used to Rate Reciprocating Compressors." Proceedings of the Gas Machinery Conference, 2005.
- [2] API Standard 618, Fifth Edition (2007), "Reciprocating Compressors for Petroleum, Chemical, and Gas Industry Services," American Petroleum Institute, Washington, D.C.

Regularly, around the world, customers tell us they receive significant value from their investment in GE's Bently Nevada® Asset Condition Monitoring products and services. Words such as "reduced downtime," "shorter outages," "increased MTBF," and "fewer process interruptions" are commonplace as they relate to us what our systems are delivering, in their own words.

To provide you with easy access to these success stories, we're pleased to announce a new web portal devoted entirely to a library of stories we've compiled over the last several years. These succinct, impactful stories use an easy-to-read one-page format that tells you what problems the customer had, how they used Bently Nevada products and services to solve those problems, how they measured their payback, and the benefits they've received.

We encourage you to visit this new portal at the URL below and see for yourself the wide variety of customers and industries that are quantitatively benefitting from our solutions.

Understanding how others are receiving value from their Bently Nevada systems and services has obvious benefits for us: we learn how to improve so we can meet your needs even better, while discovering entirely new needs you may have.



Address <http://www.ge-energy.com/ocsuccess>

GE Energy

CUSTOMER SUCCESS STORY

BENTLY NEVADA* ASSET CONDITION MONITORING

SHANGHAI SECCO PETROCHEMICAL COMPANY, LTD. - CAOJING, CHINA

"Our investment in GE's Bently Nevada condition monitoring products and services contributed significantly towards the successful start-up and operation of the SECCO complex and we now view the installed system as an integral part of our plan to achieve a 5-year run at full production capacity after the major plant outage in 2009." — Paul Bowdler, Production Director, Shanghai SECCO Petrochemical Company, Ltd.

PROBLEM

In 2002, the SECCO petrochemical facility was being designed - a highly integrated complex consisting of a 900,000 tonne/year ethylene cracker "front end" and world-scale downstream polyethylene, styrene, polystyrene, propylene, acrylonitrile, polypropylene, butadiene & aromatics plants. The huge scale of the complex resulted in a project team consisting of nine different Engineering and Procurement Contractors (EPCs) and numerous machinery OEMs. SECCO required a complex-wide, highly integrated condition monitoring system covering their entire spectrum of critical, essential, and balance-of-plant machinery. A condition monitoring supplier was required that could not only meet the stringent technical specifications, but could coordinate the numerous details necessary to ensure that the monitoring systems supplied by each machinery OEM and by the nine separate EPCs would work properly together and reflect SECCO's requirements for a comprehensive, fully integrated system.

SOLUTION

After careful review, SECCO standardized on GE's Bently Nevada asset condition monitoring products to address their needs. A significant factor in SECCO's decision was the global service capabilities represented by GE's Bently Nevada team to coordinate supply of systems and ensure consistency, and to provide necessary factory acceptance testing, site commissioning, and ongoing support at the complex.

PAYBACK

SECCO's maintenance and engineering teams have used the installed system to proactively manage the many rotating machinery assets on the complex and numerous machine "saves" have been documented during this time, validating the necessity of the condition monitoring system. SECCO's management has now established an ambitious goal of a five-year continuous run at full production capacity and the system is being expanded with additional functionality that will provide "actionable information" on all critical machinery.

BENEFITS

- **Helps extend time between scheduled outages** by delivering actionable information on machinery condition, allowing operators to balance stress on the asset against production requirements.
- **Protects machines against costly catastrophic damage and process interruptions** by continuously monitoring critical parameters indicative of overall machine condition and health of specific mechanical components such as bearings and seals.
- **Reduces system-related costs** for large, multi-plant complexes by providing an integrated condition monitoring environment - lower training costs for employees, lower support costs by dealing with a single system and a single vendor.



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 GEA17126 (09/08)

Oil & Gas - Petrochemical Production

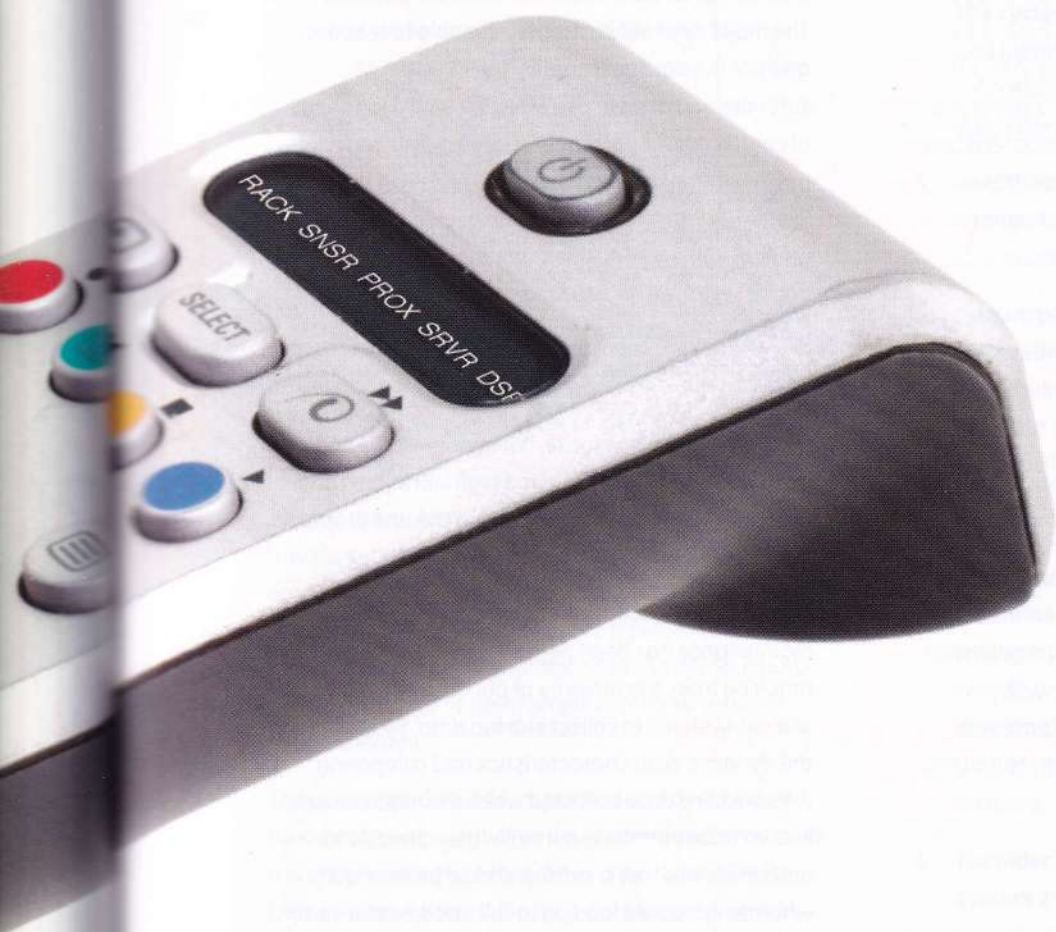
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Remote Services

Being There Without Being There



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In the not-too-distant past, I was tasked with an important assignment: identify those customers around the world that are getting the most value from their Bently Nevada* hardware, software, and service solutions. Then, determine the common denominators that separate these "best performers" from their peers. This is not to say that only the "best performers" receive value. They simply manage to extract considerably more value from our systems than their peers. It was these best-in-class customers that we wanted to understand, allowing us to help a larger percentage of those with ordinary results become those with extraordinary results. If any of you have read Stephen R. Covey's best-selling book, *The 7 Habits of Highly Effective People*, my mission is analogous: identify and articulate the common characteristics of our most highly effective customers and use their facilities as "reference sites." It is a mission that is both ongoing and highly rewarding.

In this article, I'll briefly identify those characteristics of best-in-class performers. However, an in-depth treatment of each and every trait could easily consume an entire issue of ORBIT rather than just a single article. As such, I'll be focusing instead on a particular grouping of traits. As you might have guessed from the title, it is how selected customers are using our remote service capabilities to improve their timeliness, effectiveness, and cost. Indeed, virtually every site reviewed that distinguished itself as best-in-class was using some form of remote service, regardless of whether they embodied every one of the traits that I will describe shortly.

"Average" versus "Best-In-Class"

As mentioned in the introduction, the majority of our users are receiving value from our systems. They are simply not receiving all the value that they could. An average user of our system typically employs it to monitor their critical machine trains, performing two important tasks:

1. **Reactive "Bump-in-the-night" analysis.** A machine train unexpectedly trips or encounters a high vibration alarm. The first question asked by management is whether the unit can be safely restarted, or, if it did not trip, whether it can continue to run safely. The majority of our customers are able to reactively analyze the data collected by their System 1* software and answer this question with a high level of confidence. For example, a large pulverized coal power station in the Western U.S. reviewed their System 1 data following an unexpected trip. Their analysis quickly concluded that the unit should not be restarted until the number 11 bearing was first visually examined for the presence of a rub. Inspection confirmed their analysis: a rub was indeed occurring. In this case, it was traced to a large fastener that had come loose, riding against the shaft to create the resulting rub and high vibration. The problem was quickly corrected and the unit promptly returned to service.
2. **Post-maintenance start-up monitoring.** After maintenance has been performed on a critical machine train, the majority of our customers also use our systems to collect startup data. By observing the dynamic data characteristics and comparing with baseline data collected when the machine was known to be operating normally, they are able to determine whether a startup should be aborted or whether increased loading to full rated output can safely occur. As such, they can reactively determine whether the maintenance performed was successful.

It is noteworthy that these two tasks, although inherently reactive in nature, usually provide sufficient financial justification for the entire monitoring system.

As such, they deliver measurable value. However, our best-in-class customers have progressed beyond these important (but basic) uses to proactively influence operating and maintenance decisions on a regular basis. Some of the results they are achieving include extending the time between outages, regularly determining and planning when and what kind of maintenance is required on both critical and less-critical equipment, utilizing personnel more effectively, and allowing expertise to be applied remotely rather than necessarily residing locally at each and every plant. Indeed, some have been so successful that their condition monitoring programs actually receive mention as key competitive strategies in their annual shareholder reports.

"Best-In-Class" Characteristics

Over the past 10 years, I have been a member of GE's services team for Bently Nevada Asset Condition Monitoring products. During that time, I have been involved in hundreds of projects and traveled more than 200 thousand miles visiting customers, observing their successes and failures, and helping us respond with better service capabilities and processes. Coupled with that experience is my current task of identifying reference sites globally.

Twenty characteristics have emerged as a result of my travels, separating average from best-in-class customers. While few best-in-class customers exhibit every single one of these 20 traits, they typically exhibit at least a dozen. And, as mentioned in the introduction, nearly every one of them employs remote services to some extent.

The points listed next (in no particular order of importance) can be thought of as Key Performance Indicators. It is important to note that these are not just KPIs for best-in-class systems, but best-in-class programs as well. In order to deliver high levels of value, excellent systems are necessary, but not sufficient. Excellent processes/practices must also be in place, and these processes must be followed by trained, qualified personnel at all levels. It is somewhat counter-intuitive, but of these three general areas of KPIs (Processes, People, and Technology), the easiest to satisfy is the Technology piece.

Processes

1. **Protection systems are deployed correctly and rigorously maintained.** All green lights. Fundamentals of transducer installation and system verification are followed, both at initial deployment and during outages/turnarounds.
2. **Change management is in place for racks and System 1 software configuration.** This is standard operating practice for any system where critical operational decisions will be influenced by the system outputs.
3. **The system is in use on a daily basis by operations and maintenance.** A simple measure of system utilization and realized value is sheer number of daily users.
4. **A software support plan is in place for updates.** A routine update cycle is utilized for the System 1, operating system, and anti-virus software.
5. **System performance measurements are in place with defined metrics.** For example, system server availability might be a measurement and 99.9% might be the associated metric.
6. **Alarms are dealt with to resolve the issues.** No alarm conditions are ignored.
7. **A documented process is in place to guide personnel in how to use the system and respond to displays.** The organization understands specifically how the system will be used under routine and abnormal operating conditions, and has taken the time to document this in a manner accessible to all users.
8. **For older plants, a long-term condition monitoring system expansion plan is utilized.** This focuses resources over time on the economically efficient extension of evolving technologies.
9. **KPIs for the condition monitoring system are in place.** This means they are documented, understood by system users, tracked, and periodically revised to reflect current operational needs.

10. **Success stories are documented and shared.**

The site is recognized within the customer's business as an example to be shared and its practices replicated.

People

11. **A comprehensive training plan is in place for the various functions at the site, including Maintenance and Operations.** Training is periodic and ongoing—not viewed as a one-time event for manual-data-collection personnel and primary users only.

12. **Qualification standards are implemented for all users.** This includes those who manually collect data on periodic routes, operating personnel, rotating machinery engineers, and any other users of the system.

Technology

13. **System 1 software is integrated with a process data server (preferably the DCS).** This allows correlation of observed machine conditions with process variables.

14. **The system can be easily accessed on the customer's business network domain.** Decision makers can easily view the system displays from their desks without having to access a process control network.

15. **The System 1 servers are maintained and included into the customer's IT support department.** No orphan systems.

16. **Advanced software for diagnostics is understood and in use by Operations and Maintenance.** For large plants in remote locales with reduced staffing, having a tool to focus scarce personnel resources on real problems is essential.

17. **In the initial plant design phase, process instrumentation is adequate for both current and future use by condition monitoring and control systems.** For example, to support detailed thermodynamic process analysis, inclusion of process fluid flow measurements at the time of initial plant construc-

tion is considerably less expensive than retrofitting such a measurement at a later date.

18. **Advanced condition monitoring technologies are employed on more than just critical assets.**

The deployment of advanced condition monitoring systems goes well beyond the relatively few so-called "critical" assets within the plant, and includes all manner of equipment such as small motor/pump sets and static assets such as heat exchangers, receivers, piping, and valves.

19. **Remote connectivity is enabled for system configuration, software updates, and machine diagnostics.** Remote connectivity includes customer WAN and third-party access via the Internet. The plant can easily receive support from remote expertise, and does so as required.

20. **Contractual agreements for remote support are in place.** This support may be rendered by in-house personnel, machinery OEM personnel, GE's Bently Nevada personnel, or others.

Why Remote?

In this article, I have chosen to focus on characteristics #19 and #20 because they pertain specifically to remote services. Why are remote services such an important issue among these 20 KPIs that they deserve to be singled out?

The answer is quite simple: cost.

As I'll describe next, today's systems are considerably more powerful than the systems of even a decade ago, largely because they incorporate far more data than just vibration—particularly, process data and thermodynamic performance data. This requires configuration that can often not be done at the factory and must be done once detailed site conditions are known. This leaves two options: travel to site to perform the necessary configuration, or connect remotely and do it. Obviously, remote connectivity has enormous cost-savings repercussions. The ability to remotely configure a system (and keep it configured as conditions change), in turn, enables the next major part of remote services:

Process Data Integration

There are few, if any, absolute "condition" measurements that permit accurate diagnostics without need of detailed machinery operating conditions. Indeed, it is no surprise to any experienced engineer that observed machine conditions are a direct function of how the machine is being employed.

All observable machine condition parameters such as vibration levels, tribology, and thermography must be related to the actual operating conditions as indicated by measurements such as pressure, temperature, speed, gas composition, and flows. Additionally, it is widely accepted today that calculated thermodynamic measurements for trending and alarming are extremely important. This is another driver for process data integration.

Fortunately, this data is almost always readily available from the plant control systems, or even more easily accessible in process data historians. Further, within the last decade, the advent of robust protocols for the integration of this process data to a machine condition monitoring system has enabled the widespread implementation of this critical link. The requirement for the process data, plus the widely understood ability to execute the integration, has resulted in the vast majority of recent installations to include this capability. In short, over 90% of all recent System 1 installations integrate process data to facilitate better diagnostic capabilities.



remote monitoring and diagnostic assistance, either from your own staff of machinery specialists, or ours.

A Short Historical Review

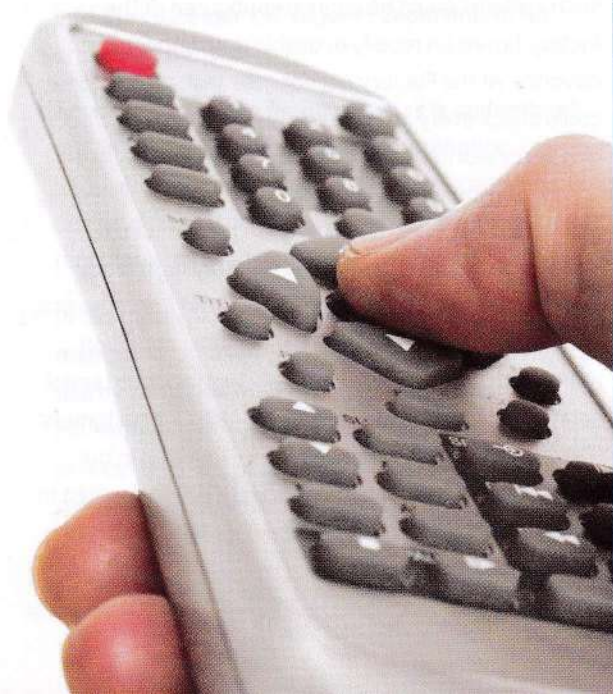
During the 1960s and 1970s, Bently Nevada products were used to pioneer many of the practices accepted as standard today. Critical machinery began to be continuously monitored and connected to automatically shut down the machine based on alarms from thrust position probes, radial vibration probes, and bearing temperature sensors. By the end of the 1970s, the inclusion of these systems on many machines had moved from being "cutting edge" to standard operating practice. It became as much a necessity for the machine to have a vibration monitoring system as it was a necessity for the machine to have a control system.

Well into the 1990s, a Bently Nevada "system" typically consisted only of transducers and a monitoring rack. Online condition monitoring software was applied on only a very small percentage of systems. Connection to the plant control system (such as the DCS) was just as frequently done with analog 4-20 mA outputs from the monitoring system as with a digital protocol, such as Modicon Modbus®. In those relatively infrequent instances when online software was used, no facilities existed for digitally exporting vibration data, or for importing process-related measurements from the plant control system or process data historian.

Such systems could be entirely configured at the factory based on readily available data known in advance. At the Factory Acceptance Test, the customer could check every loop to ensure it was labeled properly and every alarm setpoint to ensure it was configured properly. With few exceptions, the condition monitoring software (if supplied) could likewise be completely configured in advance, and the entire system ready to drop in at site. Communications to and from the rack, whether to control systems or to our own condition monitoring software, were entirely via dedicated serial connections, such as RS-485 or RS-422. Our customers' IT departments were rarely—if ever—involved in our systems because those systems were not connected to corporate data networks and did not communicate via Ethernet-type infrastructures.

Fast forward to today.

A "system" increasingly consists of not just transducers and monitoring racks, but also System 1 software for online condition monitoring. Frequently, the software is used to monitor not just rotordynamic parameters, but also thermodynamic parameters—many of which must be configured only after the plant or machine is commissioned, and many of which can change over time, requiring recurring configuration optimization. The monitor rack typically uses Ethernet-type communications to supply status, basic indication, and alarm data to the plant control system and/or sequence-of-events recorder. The condition monitoring software typically includes dozens or even hundreds of process data parameters that must be shared from the plant control system. The condition monitoring software also requires numerous configuration parameters pertaining to process details, as-commissioned machine details, site details, and other details that are simply not known at the time a system is assembled and tested at the factory, or which change once the plant, process, and/or machine is actually commissioned. Thus, only at site can the as-designed assumptions become reconciled with the as-commissioned conditions.



Citrix® Technology

While numerous customers use the available client-server architecture of System 1 software to connect a local computer running our display client to a remote computer running System 1 server software, there is also another increasingly popular technology that is being used: Citrix® Access Essentials.

The concept behind such software is essentially the same as was being used 15 years ago to remotely control a PC. The idea is to pass mouse clicks, keyboard strokes, and screen pixels from one computer to another, much as if an extremely long cable connected the mouse, keyboard, and screen on the remote computer to the host computer. A decade ago, that "extremely long cable" was a telephone line and a modem coupled with software such as Symantec's PC Anywhere™ application. Today, that "extremely long cable" is the Internet or a corporate data network coupled with Citrix Access Essentials™ software.

Why use such technology? There are numerous reasons:

- **It eliminates the need for every person accessing System 1—or any other application for that matter—to have special client software such as System 1 Display.** Display can be loaded on just a single computer and shared across every user in the enterprise, meaning it is far easier to manage licenses and keep display clients upgraded to the latest version.

- **It can access every application on the host computer, not just System 1.** Thus, if remote access requires the user to view vibration data from System 1, process data from an historian, and machinery drawings in CAD format, it is no longer necessary to have each of these applications loaded on the "display" PC. Instead, Citrix technology lets these applications on the host PC be remotely invoked and controlled from the remote "display" PC.
- **It is compatible with the IT policies and technologies being used by most customers today.** Many customers are already using Citrix solutions to enable remote connectivity for their own employees.
- **It requires no special software on each remote client other than a self-loading applet that automatically loads from the host PC.** It is no more invasive than the tiny applets that load when you visit certain websites to view animation content. IT departments can centrally control and manage this Citrix "viewer" applet and it is specifically designed to work with IT firewalls, corporate proxy servers, and other typically encountered corporate IT infrastructure components.
- **It allows user-level access controls.** Thus, when a particular user logs in, he/she might be given access to only certain applications on the host machine, while another user might have access to every application. For example, a Bently Nevada Machinery Diagnostic Services (MDS) engineer

might log in and be given access to System 1 and a view-only version of DCS screens, but be locked out from changing DCS setpoints or configuration settings in machinery control systems.

- **It allows completely independent instances of the program to be run for separate users.** For example, three users could be logged into the host computer. One might be a corporate rotating machinery engineer looking at one machine. Another might be the machinery OEM's thermodynamics specialist looking at another machine. And another might be a Bently Nevada technical support engineer doing routine system checks and updates. Each of these three individuals would be able to access the system simultaneously and have completely separate instances of the display software running with different plots, different scaling, etc.

If you have been hesitant to pursue remote connectivity because you are concerned about the number of System 1 display client software packages required to service your entire organization, and/or you need remote access to much more than just System 1 software, we invite you to contact your nearest GE sales professional specializing in Bently Nevada Asset Condition Monitoring products and ask about Citrix technology. For many of our customers, it is exactly the solution they have been seeking to provide affordable, secure, easily maintained, and highly flexible remote access for their condition monitoring needs.

Remote Configuration

Much of the configuration discussed in the preceding paragraph can be done only after the Bently Nevada system arrives at site, in sharp contrast to the situation of only a decade or two ago. However, the good news is that just because much of this configuration can be done only after the system arrives at site, it does not necessarily mean that a person has to travel to site. Remote connectivity has become the key to delivering the necessary services, without incurring all of the costs and inherent travel time associated with a normal site visit.

Refer back to our list of 20 points on pages 37 and 38. Consider that fully 15 of the 20 points outlined there are either partially or completely deliverable using remote connectivity technologies. Now, consider the costs to deliver these services if a site visit was mandatory for all of them. The time at site would be rather lengthy and most customers would expect to treat it as a one-time event where the system is configured once and left alone for the duration of its life. While the set-it-and-

forget-it approach is desirable, it simply isn't practical. Those customers that are getting the most out of their systems are using them regularly—often remotely—and also making continued adjustments to configuration details. This continually improves the results they are receiving and allows them to verify that the system is consistent with current operating conditions and machinery details.

Remote Diagnostics

Obviously, the end objective of a condition monitoring system is to use it to monitor your assets. As outlined above, the ability to remotely configure a system is precisely what allows it to monitor assets so effectively. But this begs the question, "Who is going to actually use the system to assess machinery conditions and diagnose problems?"

A decreasing number of facilities today have the luxury of a full-time rotating machinery engineer. At one time, this would have been a huge problem. Today, it is com-

SIDEBAR ARTICLE

Surmounting the IT Challenge

A major challenge for many customers is the reluctance of their Information Technology (IT) departments to grant remote access due to security concerns. However, most of our customers are surprised to learn how easily these issues can be addressed when they allow us to work with their IT departments, offloading this responsibility from the rotating machinery engineer's shoulders. We understand that this is a significant issue and we have staffed ourselves accordingly with personnel in our services organization specifically devoted to working with customer IT departments. These individuals have themselves been employed in corporate IT environments, have deep understanding of the technologies available

and used in these environments, and are fluent in the concerns and policies typically imposed on remote connectivity scenarios. In every instance, we have been able to engineer appropriate remote connectivity solutions that satisfy speed and security concerns along with adherence to the customer's corporate IT policies. As such, you can be assured that the IT challenge is no longer a major impediment to implementing remote connectivity.

There are typically three levels of preparedness that organizations align with when considering remote connectivity:

1. An organization that is ready to go—they have complete support within their organization and may need a small amount of technical services to get it going.

mon for rotating machinery engineers and condition monitoring specialists to "telecommute" by working from one location and accessing systems at many other locations to support these facilities remotely via a network. It really no longer matters whether they are at corporate headquarters, one particular plant in a multi-plant enterprise, or even the den of their own home.

In the past, the concept of rotating machinery expertise shared across facilities was extremely limited. It usually meant an engineer that was constantly on the road, moving around within a geographic region to be at different plants on different days of the week. An individual could not be in multiple places at once and the concept of remote access was highly appealing under such scenarios. However, when remote access first appeared, it relied on dial-up modems and telephone lines; access speed was often so slow due to bandwidth that although remote access was technically achievable, it was often impractical as the primary method of managing the machinery. As a result, remote access

may have modestly enhanced the effectiveness of the engineer, but did not eliminate the need for travel in most situations.

The Internet has completely revolutionized this situation. High-bandwidth, high-speed access to corporate data networks is now commonplace via secure technologies such as virtual private networking (VPN). Rotating machinery engineers can now "be there without being there" via the Internet, enjoying access speeds to data, plots, reports, and every aspect of the system just as though they were sitting at the host computer on-site. I have personally been involved with a number of projects where I can honestly say that the speed and ease-of-access to a system thousands of miles away was as good as situations where I sat in the plant and configured the system locally. Access speed is simply not a problem any longer, nor is access security.



2. An organization where implementation is probable, but may need significant technical services including (but not limited to) process and design services in order to architect a secure environment.
3. An organization that believes they have a strong cost-benefit justification for remote access services, but requires significant help in documenting the business requirements, completing a cost-benefit analysis, and taking the requirements to their IT organization to develop an implementation plan.

Using ISO/IEC 27000-series standards as a foundation, no matter where your organization aligns amid these three levels, we can provide the necessary services to enable secure remote access. These services range

from complete turnkey solutions to individualized programs including—but not limited to—site audit, risk management and analysis, technical design, and Information Technology Infrastructure Library (ITIL) service support process engineering. Regardless of the services provided, our number one priority is always to maintain the confidentiality, integrity, and availability of your critical infrastructure assets.

This comprehensive 43-page guide is used by our service engineers. It documents the various ways to install System 1 software within a corporate network environment for both local and remote connectivity while addressing the concerns of your IT department.

DOCUMENT	Version	Date	Doc ID
SYSTEM 1 INSTALLATION GUIDE	1.0	01/01/01	1000000
1. INTRODUCTION			
1.1 Purpose			
1.2 Scope			
1.3 Audience			
1.4 References			
1.5 Definitions			
1.6 Abbreviations			
1.7 Symbols			
1.8 Diagrams			
1.9 Tables			
1.10 Figures			
1.11 Appendices			
1.12 Glossary			
1.13 Index			
1.14 Revision History			
1.15 Approval			
1.16 Distribution			
1.17 Storage			
1.18 Retention			
1.19 Disposal			
1.20 Security			
1.21 Compliance			
1.22 Legal			
1.23 Environmental			
1.24 Safety			
1.25 Health			
1.26 Quality			
1.27 Reliability			
1.28 Maintainability			
1.29 Supportability			
1.30 Interoperability			
1.31 Portability			
1.32 Reconfigurability			
1.33 Scalability			
1.34 Flexibility			
1.35 Adaptability			
1.36 Extensibility			
1.37 Integrability			
1.38 Compatibility			
1.39 Interchangeability			
1.40 Reusability			
1.41 Portability			
1.42 Replicability			
1.43 Archiving			
1.44 Backup			
1.45 Recovery			
1.46 Restoration			
1.47 Migration			
1.48 Upgrade			
1.49 Downgrade			
1.50 Decommissioning			
1.51 Archiving			
1.52 Backup			
1.53 Recovery			
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1.98 Decommissioning			
1.99 Archiving			
1.100 Backup			

Remote Services – Best-in-Class Examples

Following is a brief overview of some selected reference sites that represent best-in-class programs and embody many of the aforementioned “20 characteristics.”

Customer: Large North American power producer.

Remote Capabilities: A centralized team of machinery experts at corporate headquarters remotely monitors and diagnoses machinery health at multiple plant locations.

Scenario: This customer has highly effective and efficient work package planning for routine outages/turnarounds. The use of System 1* software, in conjunction with a comprehensive machine condition monitoring program employing all available condition monitoring technologies, has significantly reduced both the cost and length of planned maintenance outages. A relatively small number of centralized “experts” supports the remote sites (consisting of mostly pulverized coal plants) from a single corporate headquarters location. This customer’s extensive deployment of cost-effective online systems to cover all types of assets at the sites further reduces the requirement for skilled condition monitoring technicians at each individual plant.

Customer: Upstream oil & gas customer in Latin America.

Remote Capabilities: Onshore monitoring of multiple offshore platforms by a centralized team of experts, along with remote system maintenance. Citrix Access Essentials is used to reduce the number of System 1 display clients that must be maintained and deployed.

Scenario: With 17 servers distributed at various onshore and offshore locations, this customer needed to upgrade to the latest version of System 1 software that added valuable features, including compressor maps. However, they also wanted an economical method that allowed central administration of all software servers and eliminated the need to travel to each offshore facility to perform the upgrades. Remote administration capabilities built-in to System 1 software allow

upgrades to be performed remotely. Special migration functionality also allows users of Data Manager* 2000 software to move to System 1 software while retaining their historical data and configuration details. Our service team accessed the offshore systems via the customer’s onshore data center in South America and upgraded eight System 1 servers and four Data Manager 2000 servers to the most current version of System 1 software, augmented by Bently PERFORMANCE* thermodynamic performance monitoring capabilities (the remaining five servers are scheduled to be addressed at a later date). The remote administration capabilities of System 1 software along with seamless migration capabilities from Data Manager 2000 to System 1 allowed what would have previously taken 10 man-weeks to be performed in just 10 days. The customer conservatively estimates the savings at 80,000 USD, not including travel to the various platforms that would have been required. They are extremely happy with the new functionality delivered, particularly the availability of compressor performance maps, allowing maintenance such as water washes to be scheduled at optimal intervals based on measured efficiency degradation.

Customer: Large North American refinery.

Remote Capabilities: The plant’s rotating machinery engineer can access the on-site condition monitoring system from home.

Scenario: A minor process upset was thought to have fouled a centrifugal compressor. Management needed to know whether to shut down the compressor and perform a water wash, or keep it running until the next turnaround. Because the customer had both rotor dynamic and thermodynamic variables and calculations available in their System 1 software, they were able to definitively ascertain that no major degradation in compressor performance had occurred, and it was safe to continue operations until the next turnaround. This evaluation was made by the plant’s rotating machinery engineer from his home in the middle of the night.



Customer: Large European power generation company with global network of plants.

Remote Capabilities: Remote fleet monitoring of all global assets via System 1 software.

Scenario: A network of System 1 servers around the world completely replicates the data set from each site at a single headquarters location for remote monitoring on a fleet scale, providing the high-level insight into their worldwide asset base that they require. The specific requirements of fleet operators, whether in the power generation or oil & gas market segments, have been repeatedly addressed by the flexible deployment of System 1 remote servers using many of the common features cited previously in this article. The needs and the associated solutions for fleet operators, whether as an OEM or a global business, are quite different than even the largest single enterprises. System 1 software is specifically engineered to address such needs.

Customer: North American independent power producer.

Remote Capabilities: The machinery OEM's lead rotating equipment engineer remotely accesses the plant's machinery regularly to advise on machinery health and diagnose problems.

Scenario: Post-outage start-ups for a large steam turbine generator at this site had always been problematic, resulting in many days of "stand-by" charges as various issues were resolved. With the installation of a firewall-friendly Citrix package, the OEM's lead rotating machinery engineer was able to easily access the System 1 server and monitor the start-up from his office. He correctly called a trim balance shot, allowing the fastest ever startup with no charges for travel, meals, hotels, or standby.

Customer: Upstream oil & gas offshore production facility in the Middle East.

Remote Capabilities: Installation and deployment of additional



System 1 software features to enable thermodynamic performance monitoring, and ongoing remote support of the installed systems.

Scenario: This customer needed more information on the state of their assets and requested we assist in the deployment of thermodynamic monitoring software. However, like many offshore sites, significant logistical challenges were present such as helicopter access, extensive training requirements, shortage of berthing space, and availability of highly experienced engineers to configure the systems. The only workable solution for the execution of this work was to require nearly all the system commissioning and optimization to be accomplished remotely using personnel thousands of miles away. Several months later, with over \$250K of avoided costs achieved, the systems were delivered to the customer's complete satisfaction. Because the site uses an extremely large network of System 1 servers, the customer realized following initial installation that a shortage of skilled IT personnel and the ongoing nature of the support required would make the use of in-house personnel impractical. Quite literally from the other side of the planet, the systems are now supported 24/7 by our own remote personnel. We routinely monitor server and network health, and perform tasks such as deployment of Microsoft® operating system upgrades, customer-specified anti-virus software upgrades, and System 1 software version upgrades.

Customer: Small North American electric power utility

Remote Capabilities: Remote support for plant operators from GE's Bently Nevada* Machinery Diagnostic Services (MDS) personnel.

Scenario: A sudden spike in vibration caused a turbine trip at this pulverized coal power site. Not entirely sure of the cause, the small utility contacted an MDS engineer for assistance in troubleshooting the problem. Within 15 minutes, the MDS engineer had remotely accessed the customer's System 1 software and started diagnostics. He advised them not to restart the turbine, as it appeared that there had been an unaccounted-for change in the heavy spot of the rotor, most likely

caused by a mass unbalance shift or loss of some rotor component. The MDS engineer further suggested that a blade shroud may have been liberated. Plant personnel opened the unit for inspection and, as expected, found a blade shroud had broken loose.

Customer: Large Chinese petrochemical complex.

Remote Capabilities: Installation and deployment of System 1 software's thermodynamic performance monitoring capabilities on a large compressor train.

Scenario: The customer required thermodynamic performance monitoring on a multi-stage compressor with inter-stage cooling. The complexity of the installation and the iterative nature of optimizing the software models and configuration would typically have required multiple trips by qualified engineers. The customer readily agreed to work with us to provide for a secure remote connection, and this was accomplished within days. After a short initial visit, the optimization and ongoing support was performed from our corporate offices, avoiding tens of thousands of dollars in cost.

Customer: Canadian oil & gas company operating a North Sea offshore complex.

Remote Capabilities: Remote support for platform operators from GE's Bently Nevada Machinery Diagnostic Services (MDS) personnel.

Scenario: This customer operates a large offshore platform in the U.K. sector of the North Sea. Through a contractual agreement with our MDS organization, as-needed remote support is provided for machinery problems that arise on the platform. Recently, a gas turbine generator train used to provide electricity to the complex tripped due to problems with the DCS. During the coastdown, a rub occurred, unbeknownst to operators, and the unit was restarted several times. Our MDS engineers were asked to assist following the startup. They identified the rub, assessed its severity, and isolated the problem to the train's turbine control

system logic that sequences the lube oil pumps. The problem was corrected before more costly damage to the machine could occur and the unit was quickly returned to full service.

[Editor's Note: For additional details, please see the article "Remote Machinery Diagnostic Services at Nexen Petroleum" on pages 10-18 in this issue of ORBIT.]

Customer: Large Scandinavian oil & gas customer.

Remote Capabilities: Centralized onshore monitoring of multiple offshore platforms by a team of experts using System 1 software.

Scenario: The customer monitors more than a dozen offshore facilities from a centralized onshore facility specifically dedicated to remote monitoring of machinery health. They have eliminated the travel required to effectively monitor the assets and are able to make real-time operating and maintenance decisions. Of particular benefit to them is the ability to monitor thermodynamic performance on their gas turbine assets. Because they are taxed on certain emissions, the ability to reduce these emissions by making operating adjustments is vital and has resulted in significant cost savings. Several other rotordynamic machinery problems have been remotely diagnosed and corrected as well, before more extensive damage could occur.

[Editor's Note: For additional details, please see the article "Hydro Oil & Energy's New North Sea Operations Center Cuts Production Losses" on pages 24-32 of ORBIT Vol. 27, No. 1, 2007. Note also the company is now called StatoilHydro as the result of a 2008 merger.]

Customer: North American oil & gas company.

Remote Capabilities: Centralized onshore monitoring of multiple offshore facilities by a team of corporate experts using System 1 software.

Scenario: Working closely with the customer's upstream corporate team, a standard network topology was agreed upon for a System 1 software installation permitting remote access. The software configuration includes templates for identical machine trains whereby a single view to the machine condition is provided.

Centralized corporate rotating machinery resources can now access any of the more than one dozen sites. Working with standardized machine views and plot sessions, these centralized resources help local, site-based teams resolve difficult machine issues that have probably been solved elsewhere within the customer's network of facilities, but were previously not easily shared amongst facilities. Best practices are now widely shared on the customer's internal WAN.

Conclusion

Remote services are no longer a novelty. They are being delivered routinely around the world and are an integral part of our best-in-class customers' systems and programs for machinery condition monitoring. While the benefits of such remote services are numerous, they all tie back to cost savings, without pitting quality against cost. The quality with which we can deliver many services remotely actually exceeds that of locally delivered services because the best person for the task at-hand can be used rather than the closest person geographically. The timeliness with which we can deliver services is greatly enhanced as well. Crossing international borders is no longer a problem. Airplane schedules are no longer a problem. Inclement weather is no longer a problem. A computer, an Internet connection, and an individual with the right expertise is now all that is required. 

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New RCK-1 Recip Simulator

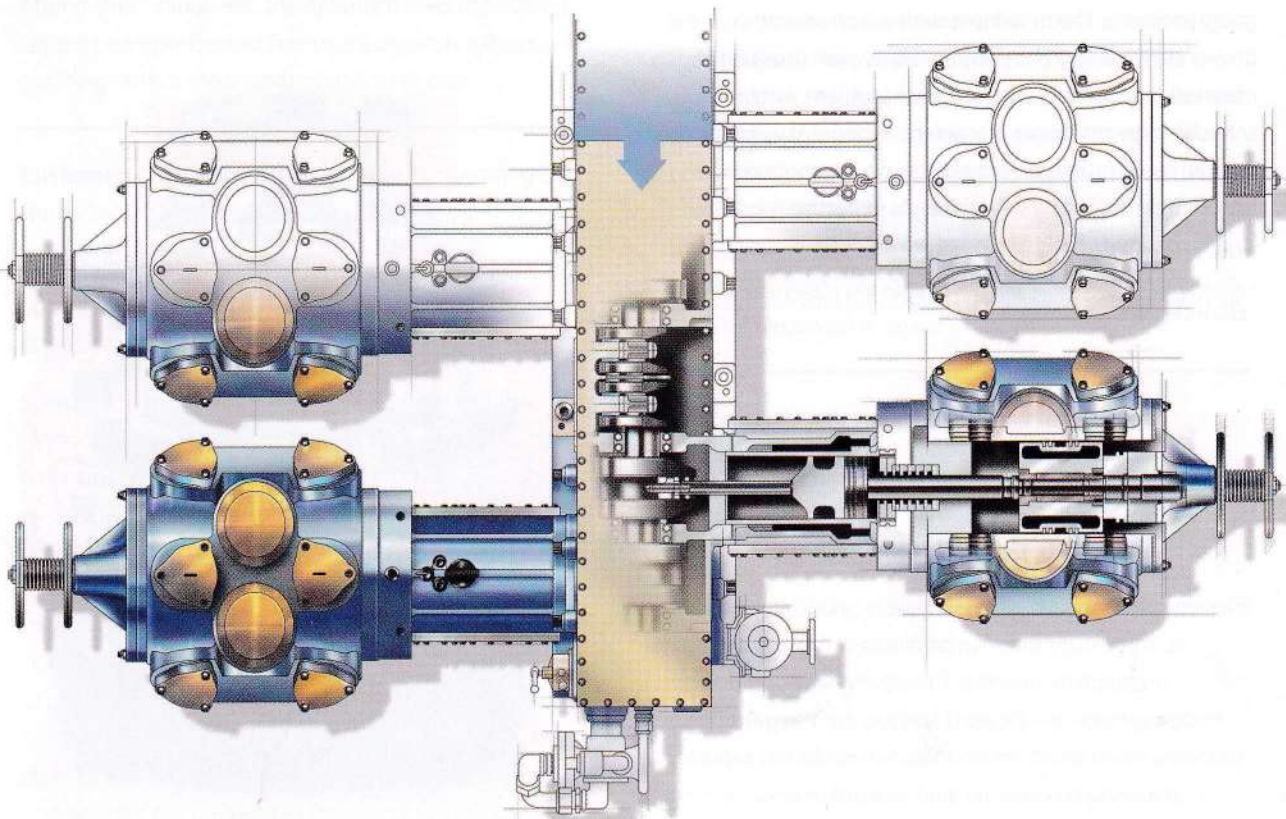
Does for reciprocating compressors what our famous rotor kit does for rotating machines

Many customers are familiar with our rotor kit (see sidebar article). We now provide a similar machinery simulator designed specifically for reciprocating compressors.

The RCK-1 is a single-cylinder, single-stage, dual-action compressor that simulates the mechanical function of an industrial reciprocating compressor. The RCK-1 incorporates transducers that measure Crank Frame

Velocity, Crosshead Acceleration, Rod Position, Crank and Head End Cylinder Pressure, Gas and Valve temperature for both Suction and Discharge, along with Single-Event and Multi-Event Timing for precise measurement of crank rotation.

The RCK-1 can simulate common reciprocating compressor faults such as valve and piston ring leaks, and mechanical drive train wear in the form of connecting rod bearing clearance. The kit equips





each head with a pair of bypass blocks (patent pending) that allow the inducement of small valve leaks at any of the suction or discharge valves. The leak can then be detected directly via analysis of the Pressure vs. Volume characteristics, or indirectly via analysis of the Gas and Valve temperature outputs.

When used in conjunction with a 3500 series monitoring system and System 1* software, the kit is a valuable training tool for demonstrating operation of our reciprocating compressor machinery management solution.

Like our original rotor kit, the RCK-1 was originally envisioned as a tool for our salespeople and our own customer training teams. However, like our rotor kit, our new RCK-1 "recip kit" is available directly to customers as well, and will be of particular interest to research labs and training facilities dealing with reciprocating compressors.

Fully functional RCK-1 Recip Simulators will be available for demonstrations at our Minden, Nevada headquarters as well as our eight regional Customer Application Centers around the world. For additional information, contact your nearest GE salesperson specializing in Bently Nevada* Asset Condition Monitoring products and services. 

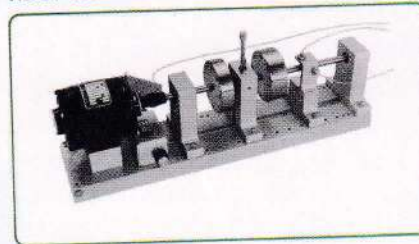
* denotes the trademarks or registered trademarks of Bently Nevada, LLC, a General Electric company.

SIDEBAR ARTICLE

The Bently Nevada Rotor Kit

The original Bently Nevada RK-1 rotor kit was introduced in 1964 as a way to simulate common rotor malfunctions such as rubs and imbalance. It allowed our salesforce to physically demonstrate the operation of proximity probes on rotating machinery, helping customers understand how probes work, the kinds of information they can provide, and the kinds of malfunctions they can detect. Today, we are on our 4th generation of rotor kits with the RK-4, and use has broadened far beyond the original intended audience of our own salesforce to include research laboratories and customer facilities such as training centers and rotating machinery departments.

Rotor Kit



INTRODUCTION

The Bently Nevada Generation Rotor Kit provides basic dynamic motion simulation in a compact, easy-to-use package. The Rotor Kit serves as a useful training tool, capable of simulating rotor dynamics found in rotating machinery.

An optional Precision/Interconnect Kit provides a convenient means of interfacing X-Y radial vibration, frequency and oil film sensor. Frequency analysis to observe rotor dynamic behavior and to test Bently Nevada diagnostic equipment on Bently Nevada Compressor simulators.

FUNCTION

The Rotor Kit demonstrates:

- Shut-In Run
- Keyphasor
- Shut-In Vibration and Position
- Balance Pressure Regime (Control)
- Unbalance
- Product Effects
- Mathematical "Kinetics"

With the addition of available options, the Rotor Kit can also demonstrate:

- Oil Film and Oil Whip Effects
- Effects of Dynamic Shaft Perturbations

FEATURES

The Rotor Kit includes:

- Frequency Display Unit & Frequency Probe* (X, Y and Keyphasor plus speed)
- 10,000 RPM Motor
- Motor Speed Control
- Two Drive Bearing Blocks
- Rub (Sensor/Extension) Limiter
- Two Rotor Masses
- Spacer Parts and Balance Weights
- Allen Wrench Tools

**BENTLY
NEVADA**

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8071



Nine Mile Point
Nuclear Station



H.A. Wagner Power Plant



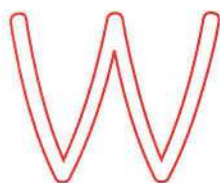
Corporate Headquarters



Calvert Cliffs
Nuclear Power Plant

Moving Data, Not People at Constellation Energy

Using the ADRE 408 DSPi over a corporate data network*



orking in a deregulated power market presents unique challenges from a machinery monitoring standpoint. The primary challenge faced is monitoring a diverse portfolio of steam turbine generators across a wide geographical area from a centralized corporate engineering location. Issues include travel costs, manpower, and juggling the work/life balance.

Our typical practice is to monitor vibration parameters for major equipment going into and returning from an outage. Our preferred method is to collect data using a continuous management system, such as GE's System 1* software, and review the data at our corporate engineering office. Unfortunately, we do not have continuous management available on all of our major equipment. To supplement our systems, we have several ADRE* 408 DSPi that can be deployed to collect this critical operating data.

One of our favorite features of the 408 is its ability to be connected to our Corporate Data Network (CDN). This feature allows us to review data at our office. Because of the network hardened status of the 408, our IT department is willing to allow us to connect the device to any part of our CDN without concern – meaning that anywhere we can find a network connection, we can collect data remotely.

On a recent weekend we encountered a "perfect storm:" a steam turbine returning from a major overhaul in northern Maryland, a steam turbine rolling down to start an outage in southern Maryland, and a shorted-turn test on a generator in New York. Trying to cover these three important events with a staff of only two qualified analysts would be daunting, to say the least. However, when these three machines are in three different locations a combined 370 miles away from one another, it adds another level of complexity. Without the network capabilities of the 408, three analysts would have had to be at three sites simultaneously collecting data on

these three machines. By utilizing three 408s, and the ADRE Sxp software, these three events were monitored remotely by one individual, from his usual office. The 408's were shipped to their respective locations, connected by plant personnel and configured in place by the analyst working from his normal location. The 408s not only allowed one analyst to perform the job of three, it also turned a weekend that would have been dominated by travel for three analysts into a single day of work for one analyst.

In addition to the time saved from the networking capabilities of the 408s, the ability to stream many channels of real-time data allowed the analyst to identify a seal rub in real time and provide direction to the plant operations staff. This direction allowed the rub to clear without having to trip the steam turbine and risk a more significant rub during the subsequent roll down on the newly overhauled steam turbine. Further, having the ability to make this call in real time saved hours of time to roll the unit down, go on turning gear for the bow to work out, and subsequent restart time and costs. This allowed us to get back on line faster and reduce the collateral damage and loss of efficiencies that a shutdown may have incurred. The 408 DSPi combined with ADRE Sxp software creates a powerful and versatile data analysis platform that saves us significant costs that would have been wasted on travel or waiting around for a machine to run. The 408 DSPi truly allows us to move data and not people. 

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2009 TRAINING CALENDAR

For 2009, we are pleased to offer nearly 120 scheduled training courses for our Bently Nevada* Asset Condition Monitoring hardware and software.

These courses are available at locations worldwide and while most courses are offered in English, an increasing number are also available in local languages to better serve our global customers. For course descriptions and

additional information, contact your nearest GE sales professional specializing in Bently Nevada products.

You can also visit us at www.ge-energy.com/training and click on "Equipment & Software Training" for the most current version of schedules and course descriptions.

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Dates	Language	Location	Duration (days)	Course Number	Price
GETTING THE MOST FROM ADRE SXP/408 DSPI					
Feb 24-26	English	Minden, NV	3	OCMON230S0909	1900 USD
Mar 17-19	English	Houston, TX	3	OCMON230H1209	1900 USD
Apr 21-23	English	Salem, VA	3	OCMON230V1709	1900 USD
Apr 21-23	English	Warrington, UK	3	OCMON230W1709	900 GBP
Jul 21-23	English	Houston, TX	3	OCMON230H3009	1900 USD
Aug 25-27	English	Minden, NV	3	OCMON230S3509	1900 USD
Sep 01-03	English	Schenectady, NY	3	OCMON230S3609	1900 USD
Sep 22-24	English	Warrington, UK	3	OCMON230W3909	900 GBP
Nov 03-05	English	Schenectady, NY	3	OCMON230S4509	1900 USD
Dec 01-03	English	Rotterdam, Netherlands	3	OCMON230R4909	1600 EUR
Jun 11-12	German	Neu-Isenburg, Germany	2	OCMON230G2409	1575 EUR
Sep 10-11	German	Neu-Isenburg, Germany	2	OCMON230G3709	1575 EUR
LEVERAGING DECISION SUPPORT SOFTWARE					
Dec 08-10	English	Rotterdam, Netherlands	3	OCLDS200R5009	1600 EUR
MAXIMIZING THE BENEFIT OF SYSTEM 1 SOFTWARE					
Jan 27-29	English	Minden, NV	3	OCSYS200M0509	1900 USD
Feb 10-12	English	Warrington, UK	3	OCSYS200W0709	900 GBP
Feb 17-19	English	Houston, TX	3	OCSYS200H0809	1900 USD
Mar 04-06	English	Minden, NV	3	OCSYS200M1009	1900 USD
Mar 31-Apr 02	English	Salem, VA	3	OCSYS200V1409	1900 USD
Apr 14-16	English	Rotterdam, Netherlands	3	OCSYS200R1609	1600 EUR
Apr 28-30	English	Houston, TX	3	OCSYS200H1809	1900 USD
Jun 03-05	English	Florence, Italy	3	OCSYS200FI2309	1600 EUR
Jun 16-18	English	Houston, TX	3	OCSYS200H2509	1900 USD
Jun 23-25	English	Warrington, UK	3	OCSYS200W2609	900 GBP
Jul 21-23	English	Minden, NV	3	OCSYS200M3009	1900 USD
Aug 11-13	English	Schenectady, NY	3	OCSYS200S3309	1900 USD
Aug 18-20	English	Houston, TX	3	OCSYS200H3409	1900 USD
Sep 08-10	English	Minden, NV	3	OCSYS200M3709	1900 USD
Sep 22-24	English	Houston, TX	3	OCSYS200H3909	1900 USD
Oct 06-08	English	Warrington, UK	3	OCSYS200W4109	900 GBP
Dec 08-10	English	Minden, NV	3	OCSYS200M5009	1900 USD
Dec 15-17	English	Houston, TX	3	OCSYS200H5109	1900 USD
Dec 15-17	English	Rotterdam, Netherlands	3	OCSYS200R5109	1600 EUR
Feb 24-26	Norwegian	Bergen, Norway	3	OCSYS200B0909	15000 NOK
Sep 15-17	Norwegian	Bergen, Norway	3	OCSYS200B3809	15000 NOK

Dates	Language	Location	Duration (days)	Course Number	Price
BASIC VIBRATION ANALYSIS					
Mar 10-13	Norwegian	Bergen, Norway	3	OCBVA200B1109	15000 NOK
Sep 22-24	Norwegian	Bergen, Norway	3	OCBVA200B3909	15000 NOK
BALANCING FUNDAMENTALS					
Nov 17-19	English	Minden, NV	3	OCBAL200M4709	1900 USD
MACHINERY DIAGNOSTICS					
Feb 02-06	English	Minden, NV	5	OCMDS200M0609	3000 USD
Feb 16-20	English	Warrington, UK	5	OCMDS200W0809	1500 GBP
Mar 02-06	English	Salem, VA	5	OCMDS200V1009	3000 USD
May 04-08	English	Rotterdam, Netherlands	5	OCMDS200R1909	2650 EUR
May 11-15	English	Minden, NV	5	OCMDS200M2009	3000 USD
Jun 08-12	English	Florence, Italy	5	OCMDS200FI2409	2650 EUR
Jun 22-26	English	Houston, TX	5	OCMDS200H2609	3000 USD
Jul 20-24	English	Schenectady, NY	5	OCMDS200N3009	3000 USD
Aug 17-21	English	Minden, NV	5	OCMDS200M3409	3000 USD
Sep 28-Oct 02	English	Rotterdam, Netherlands	5	OCMDS200R4009	2650 EUR
Oct 26-30	English	Houston, TX	5	OCMDS200H4409	3000 USD
Nov 02-06	English	Florence, Italy	5	OCMDS200FI4509	2650 EUR
Dec 07-11	English	Warrington, UK	5	OCMDS200W5009	1500 GBP
Mar 09-13	French	Nantes, France	5	OCMDS200NF1109	2625 EUR
Jun 08-12	French	Nantes, France	5	OCMDS200NF2409	2625 EUR
Oct 12-16	French	Nantes, France	5	OCMDS200NF4209	2625 EUR
Jun 16-19	German	Neu-Isenburg, Germany	4	OCMDS200G2509	2650 EUR
Sep 29-Oct 02	German	Neu-Isenburg, Germany	4	OCMDS200G4009	2650 EUR
Mar 23-27	Norwegian	Bergen, Norway	5	OCMDS200B1309	22500 NOK
Oct 12-16	Norwegian	Bergen, Norway	5	OCMDS200B4209	22500 NOK
MACHINERY FUNDAMENTALS & APPLIED DIAGNOSTICS					
Jun 15-19	English	Florence, Italy	5	OCMDS300FI2509	2650 EUR
Oct 05-09	English	Rotterdam, Netherlands	5	OCMDS300R4109	2650 EUR
ADVANCED MACHINERY DIAGNOSTICS					
May 18-22	English	Houston, TX	5	OCMDS400H2109	3000 USD
Nov 09-13	English	Florence, Italy	5	OCMDS400FI4609	3000 EUR
APPLIED MACHINERY DIAGNOSTICS					
Nov 09-13	Norwegian	Bergen, Norway	5	OCAMD300B4609	22500 NOK
Jun 22-25	German	Neu-Isenburg, Germany	4	OCAMD300G2609	2650 EUR
Oct 05-08	German	Neu-Isenburg, Germany	4	OCAMD300G4109	2650 EUR
RECIPROCATING COMPRESSOR CONDITION MONITORING & DIAGNOSTICS					
Jun 05-07	English	Houston, TX	3	OCREC200H1909	1900 USD
Aug 25-27	English	Houston, TX	3	OCREC200H3509	1900 USD
Oct 12-14	English	Rotterdam, Netherlands	3	OCREC200R4209	1600 EUR
Nov 16-18	English	Florence, Italy	3	OCREC200FI4709	1600 EUR
SYSTEM 1 SOFTWARE FUNDAMENTAL AND APPLIED DIAGNOSTICS					
Mar 30-Apr 02	Chinese	Shanghai, China	4	OCSYD200C1409	17000 RMB
May 25-28	Chinese	Shanghai, China	4	OCSYD200C2209	17000 RMB
Nov 02-05	Chinese	Shanghai, China	4	OCSYD200C4509	17000 RMB

Dates	Language	Location	Duration (days)	Course Number	Price
FUNDAMENTALS OF VIBRATION AND TRANSDUCER OPERATION					
Feb 09-10	English	Houston, TX	2	OCBAS200H0709	1500 USD
Mar 02-03	English	Minden, NV	2	OCBAS200M1009	1500 USD
May 11-12	English	Warrington, UK	2	OCBAS200W2009	600 GBP
May 27-28	English	Warrington, UK	2	OCBAS200W2209	600 GBP
Jun 01-02	English	Minden, NV	2	OCBAS200M2309	1500 USD
Jun 08-09	English	Houston, TX	2	OCBAS200H2409	1500 USD
Sep 21-22	Dutch	Rotterdam, Netherlands	2	OCBAS200R3909	1050 EUR
Oct 12-13	English	Houston, TX	2	OCBAS200H4209	1500 USD
Nov 02-03	English	Warrington, UK	2	OCBAS200W4509	600 GBP
Nov 16-17	English	Schenectady, NY	2	OCBAS200S4709	1500 USD
3300 OPERATION AND MAINTENANCE					
Feb 03-05	English	Salem, VA	3	OCMON200V0609	1900 USD
Mar 24-26	English	Minden, NV	3	OCMON200M1309	1900 USD
Apr 29-May 01	English	Warrington, UK	3	OCMON200W2209	900 GBP
Oct 27-29	English	Schenectady, NY	3	OCMON200S4409	1900 USD
3500 OPERATION AND MAINTENANCE					
Jan 20-22	English	Minden, NV	3	OCMON210M0409	1900 USD
Feb 11-13	English	Houston, TX	3	OCMON210H0709	1900 USD
Feb 24-26	English	Salem, VA	3	OCMON210V0909	1900 USD
Mar 31-Apr 02	English	Minden, NV	3	OCMON210M1409	1900 USD
Apr 21-23	English	Houston, TX	3	OCMON210H1709	1900 USD
May 13-15	English	Warrington, UK	3	OCMON210W2009	900 GBP
May 18-20	Dutch	Rotterdam, Netherlands	3	OCMON210R2109	1600 EUR
Jun 03-05	English	Minden, NV	3	OCMON210M2309	1900 USD
Jun 10-12	English	Houston, TX	3	OCMON210H2409	1900 USD
Jul 07-09	English	Minden, NV	3	OCMON210M2809	1900 USD
Aug 11-13	English	Houston, TX	3	OCMON210H3309	1900 USD
Sep 15-17	English	Houston, TX	3	OCMON210H3809	1900 USD
Sep 22-24	English	Schenectady, NY	3	OCMON210S3909	1900 USD
Sep 23-25	Dutch	Rotterdam, Netherlands	3	OCMON210R3909	1600 EUR
Oct 14-16	English	Houston, TX	3	OCMON210H4209	1900 USD
Oct 20-22	English	Minden, NV	3	OCMON210M4309	1900 USD
Nov 04-06	English	Warrington, UK	3	OCMON210W4509	900 GBP
Nov 18-20	English	Schenectady, NY	3	OCMON210S4709	1900 USD
Dec 08-10	English	Houston, TX	3	OCMON210H5009	1900 USD
Sep 22-24	French	Nantes, France	3	OCMON210NF3909	2100 EUR
Feb 16-19	Chinese	Shanghai, China	4	OCMON210C0809	13000 RMB
Apr 19-22	Chinese	Shanghai, China	4	OCMON210C1709	13000 RMB
Jun 14-17	Chinese	Shanghai, China	4	OCMON210C2509	13000 RMB
Aug 10-13	Chinese	Shanghai, China	4	OCMON210C3309	13000 RMB
Oct 19-22	Chinese	Shanghai, China	4	OCMON210C4309	13000 RMB
Dec 14-17	Chinese	Shanghai, China	4	OCMON210C5109	13000 RMB
Jun 09-10	German	Neu-Isenburg, Germany	2	OCMON210G2409	1575 EUR
Sep 08-09	German	Neu-Isenburg, Germany	2	OCMON210G3709	1575 EUR
Feb 10-12	Norwegian	Bergen, Norway	3	OCMON210B0709	15000 NOK
Sep 01-03	Norwegian	Bergen, Norway	3	OCMON210B3609	15000 NOK
GATECYCLE SOFTWARE PLANT THERMODYNAMICS MODELING					
Mar 23-27	English	Minden, NV	5	OCPER300M1309	3000 USD
Jun 15-19	English	Minden, NV	5	OCPER300M2509	3000 USD
Oct 05-09	English	Minden, NV	5	OCPER300M4109	3000 USD



How the INTERNET has revolutionized SERVICE DELIVERY

It has become almost passé to discuss how the Internet has changed our lives.

Sure, it's a thrill to fetch \$20 for that useless junk you were going to throw out, only to discover that people will actually outbid one another for it on eBay®. And yes, we all know the success stories of online retailers such as Amazon® and iTunes® that would not have been possible without the World Wide Web.

But the Internet has also dramatically changed the way that "conventional" businesses, such as ours, operate.

Nowhere is that more evident than in the way we deliver services today. Fifteen years ago, an "average" Bently Nevada system consisted only of probes and monitor racks. Today, an "average" system is far more likely to include condition monitoring software such as System 1.

While it is heartening to see industry relying more heavily on proactive, online condition monitoring rather than just reactive machinery protection, until now there has always been a serious limiting factor. Namely, our customers' ability to get value from our online software systems has depended on whether they have the resident expertise in their plants to not just interpret condition monitoring data, but to adequately configure and maintain their condition monitoring software. This element is absolutely key. Without it, customers cannot obtain valuable, reliable, and consistent data. And without this data, they cannot make high-confidence decisions regarding their operations, their maintenance, and their business as a whole.

Unlike machinery protection hardware that typically contains a limited number of parameters that must be configured, such as alarm delay times and full scale ranges, today's condition monitoring software often has hundreds of input points and thousands of highly process- and installation-dependent parameters that have to be configured at site: everything from bearing clearances to bearing types to shaft diameters to gas composition to firing temperatures to ambient humidity. In many cases, it simply isn't possible to configure all of these parameters in advance because certain details aren't known until the machines are installed, the plant control system brought online, and the process started. Yet it is these configuration "details" that separate those who are able to obtain only modest results from their system from those who obtain 5, 10, or 20 times the results of their peers. In tangible terms,



this is the difference between a plant that simply trips a refinery pump after a leak occurs, hoping the action will be adequate before a fire can ensue, versus a more proactive plant that addresses the root causes of pump leaks and failures. Such was the situation I encountered recently during customer visits in the US Gulf Coast. One had managed to eliminate their pump failures (not just reduce their consequences) while the other was merely trying to minimize the consequences without treating the root cause. One had configured their system with the details necessary to really detect failures at an early stage and help prevent them, while the other had just done minimal configuration on their system to alert them of catastrophic failures after they occurred.

To put this matter of configuration details another way, 15 years ago—just as it is today—it was possible to fully configure the machinery protection system at the time of factory acceptance testing. However, the ability to fully configure the condition monitoring software at the time of factory acceptance testing, with the hundreds or even thousands of details necessary for it to function properly, is no closer today than it was 15 years ago. Why? Because the necessary details simply are not available until the system arrives in the field and the dozens of other inter-related machines, processes, and parameters upon which the condition monitoring system relies have been commissioned.

While the Internet has not changed when we can configure the condition monitoring software, it has completely revolutionized how and where we can configure the software. Likewise, it has changed how, where, and when we can access these systems to help our customers interpret their condition monitoring data.

It is truly astonishing when I consider what the services organization I lead is not only capable of doing, but is actually doing on a daily basis. For example, an Eastern European customer has a huge facility in an extremely inaccessible location. Further, obtaining visas to travel into and out of the country makes it virtually impossible to do anything spur-of-the-moment as needs arise. At one time, the only option would have been to embed numerous people at site for months at a time, at great cost to the customer, and at great cost to our people in terms of how much time they must spend away from their families and the comforts of home. Today, the majority of work that would have occurred on-site is now occurring remotely via secure Internet connections. More specifically, this particular plant relies heavily on thermodynamic performance monitoring. An engineer in the U.K. has developed virtually every screen required as well as the basic thermodynamic models for this plant from the den in his home. He sleeps in his own bed at night and eats dinner with his family. The customer pays only for the work performed, not travel and per-diem charges. Another engineer helps configure the numerous System 1 servers required for this installation. Still another engineer on a completely different continent is helping this customer diagnose machinery problems by looking at their data online, in real time.

This is not an isolated incident. In fact, it is increasingly becoming the rule rather than the exception that remote delivery of services is being used to execute projects, regardless of size, and then to help customers use their systems on an ongoing basis. Customers in Asia receive assistance in remotely balancing a turbine by our rotordynamic specialists in Atlanta, Georgia.



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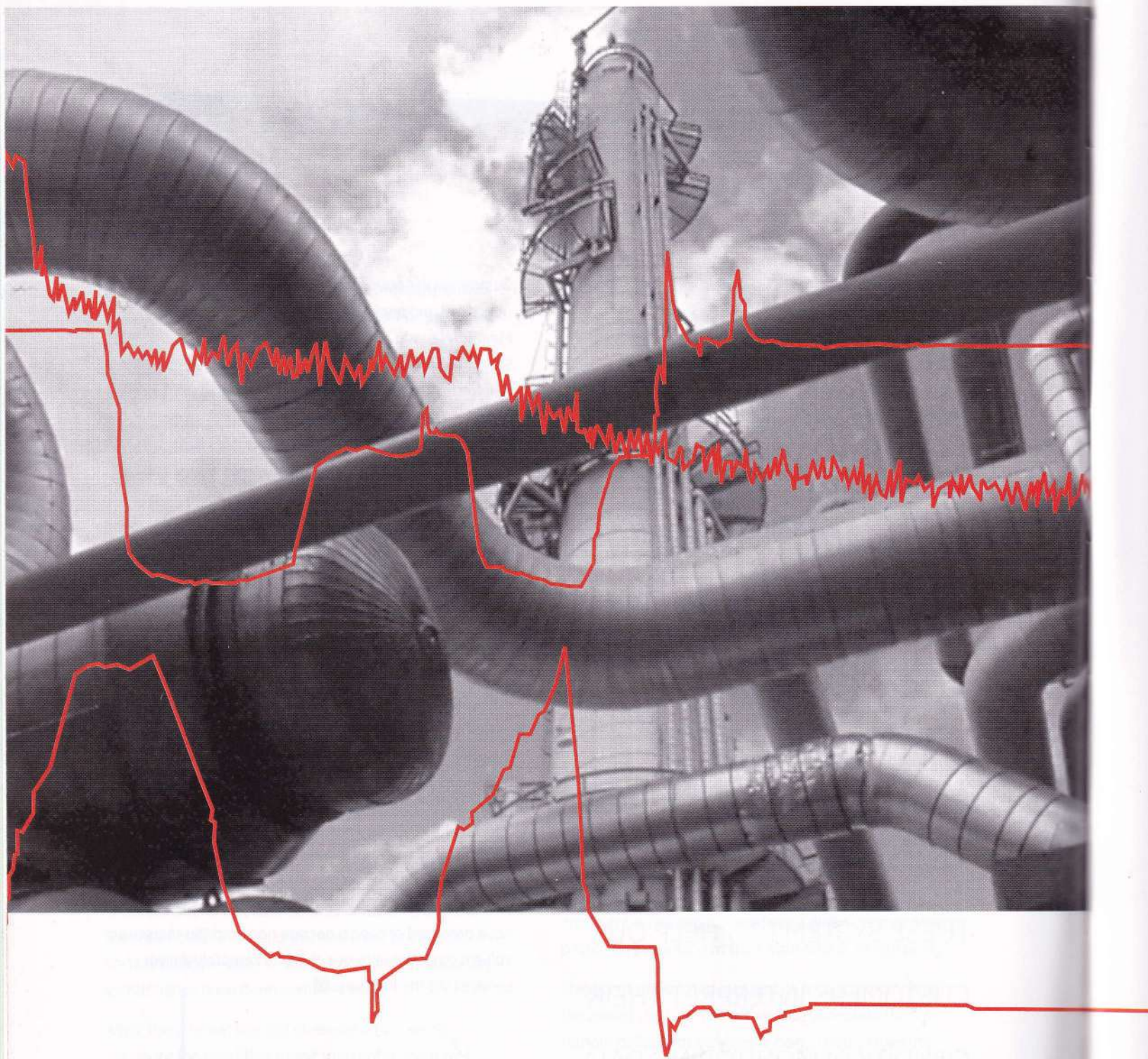
Customers in South America have their software upgraded and configured by our service engineers in Minden, Nevada. Customers on offshore platforms near Scotland have our machinery diagnostics personnel in The Netherlands access data in real time to tell them exactly why their machinery is having problems. Our engineers in India remotely connect to systems in Azerbaijan to help commission new machinery and collect baseline data.

I could go on almost indefinitely. The point is that this technology is no longer a laboratory curiosity or a bullet point of questionable veracity in a brochure—it is being used every day to solve many of our customers' most important problems.

I am extremely proud of the services team I lead and the expertise they possess. But at one time, this expertise could really only be applied by transporting people to site. Expertise had to reside locally. Today, the expertise can reside virtually anywhere there is an Internet connection.

Has the Internet changed the way we can offer service? Dramatically. Many of our customers are realizing more value from their Bently Nevada systems than we could have dreamed of even a decade ago. And this increased value is largely due to our ability to remotely deliver services via the Internet. **U**





Diagnosing

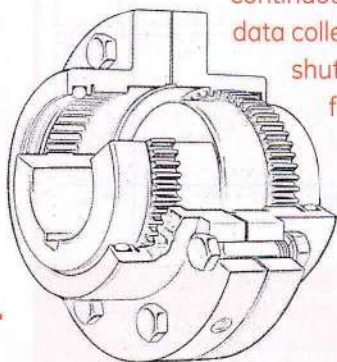
a coupling problem on a charge gas train

How vibration data and a logical process of elimination saved millions in downtime

An ethylene plant experienced a vibration issue after start-up of a multi-unit charge gas train following a relatively short mitigation outage in August 2006. The charge gas compressor has five stages of compression via three different compressor bodies. All three are driven by a 35,000 hp steam turbine with a design speed of 5,300 rpm (Figure 1). The compressors were originally installed in the late 1960s and still had the original floating oil ring design and lubricated gear couplings. The rotors had been upgraded with rub-tolerant internal seals and spherically seated tilt-pad bearings.

The short duration of the outage limited the work scope to overhauls of the A and C compressor bodies only. The C compressor had exhibited performance problems thought to be caused by fouling, while the A compressor was overhauled as a result of recent vibration issues. The B compressor was not opened up because it had no mechanical or performance problems. The inboard bearing on the discharge end of the B compressor (bearing 5) was changed because it was felt that the clearance had increased.

The train is monitored via a Bently Nevada* 3500 series machinery protection system and all critical trains in the ethylene unit were connected to Bently Nevada Data Manager* 2000 (DM2000) software to provide continuous condition monitoring and machinery diagnostic capabilities. For increased data collection resolution, an ADRE* portable data acquisition system was used to capture shutdown and startup transient data and augment the data available from the online software.



THE ETHYLENE UNIT DETAILED IN THIS CASE HISTORY HAS SUBSEQUENTLY BEEN UPGRADED TO SYSTEM 1* SOFTWARE WHICH ADDRESSES MANY OF THE DATA RESOLUTION LIMITATIONS THAT WERE INHERENT IN DM2000 SOFTWARE.

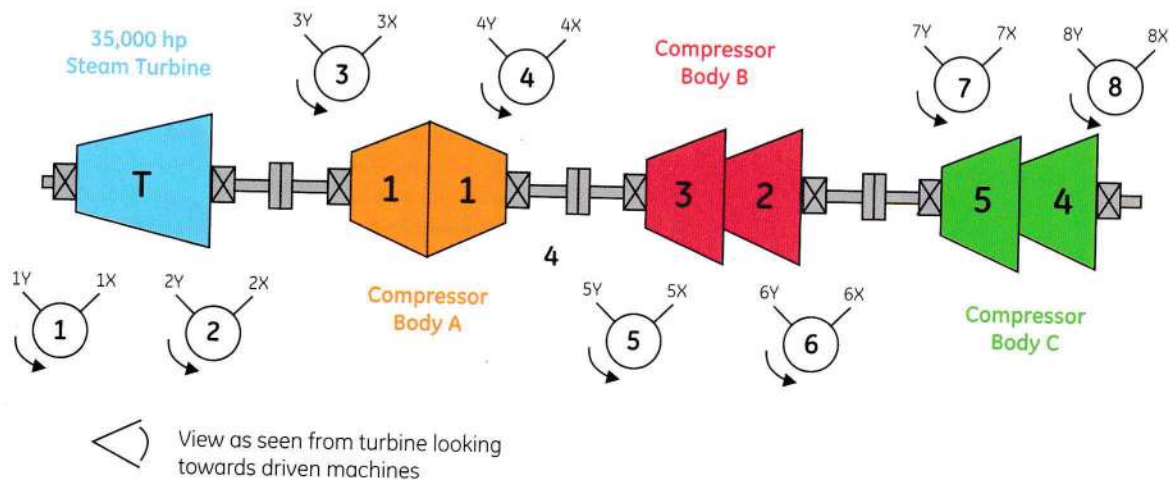


Figure 1. Machine train diagram of charge gas compressor train showing A-B-C compressor bodies, five compression stages, and proximity probe arrangements for all eight radial bearings.

Problem

Approximately 10 minutes after the charge gas compressor train was restarted following the outage, radial vibration on the B compressor increased rapidly. Although the speed remained basically unchanged, the radial vibration went from 0.5 to over 3 mils, as can be noted in Figure 2. This increase in vibration occurred immediately after the compressor train surged. Note the large increase in vibration amplitude even though the speed remained relatively constant on the right side of Figure 2. The vibration amplitude continued to rise after startup as the load on the compressor train was increased in response to increasing unit rates.

Overall amplitudes had reached approximately 4.5 mils by early September with a short excursion in late September above 5.5 mils.

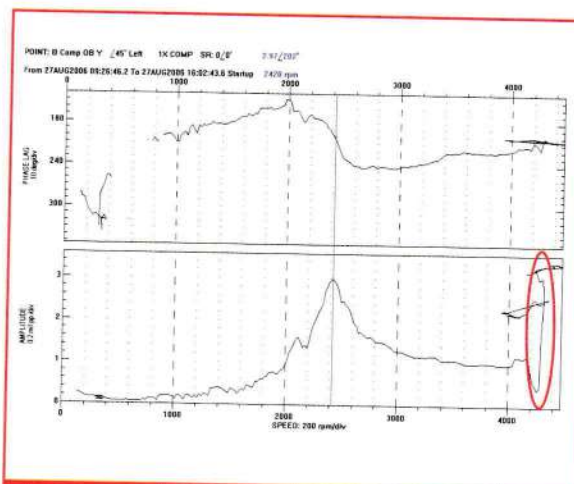


Figure 2. Bode plot of bearing #6 y-probe during start-up on 8/27/06. Note substantial change in vibration amplitude while speed remains essentially constant at approximately 4,300 rpm (region enclosed by the red oval). The blue cursor position shows the first balance resonance for this machine occurs at about 2400 rpm.

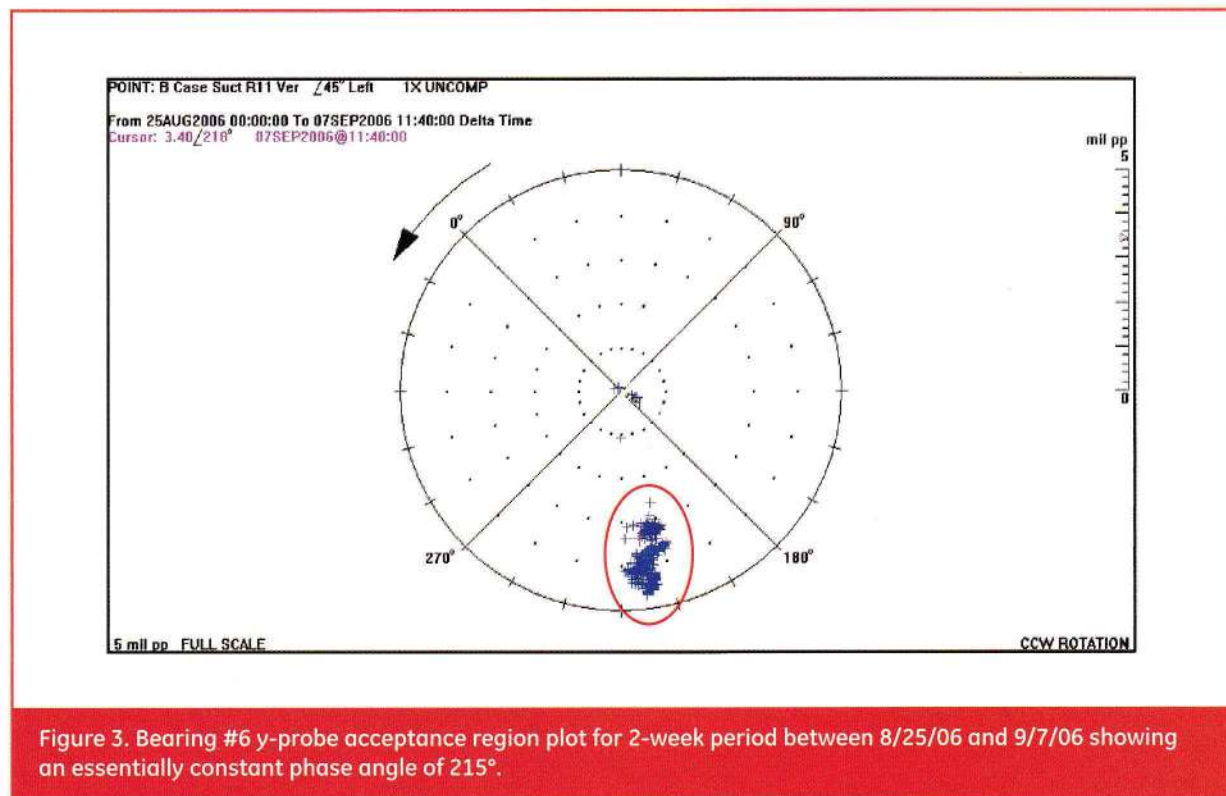
Vibration Analysis

Analysis of the problem was essentially a process of elimination whereby the available data was examined to systematically determine what was not causing the vibration. Five separate malfunctions were considered.

1. Unbalance

An initial assumption by plant operations personnel was that the high radial vibration on the B compressor was caused by unbalance. This assumption was not without basis since olefins charge gas is considered to be a fouling service. In particular, this compression train had experienced heavy fouling several years in the past. Two other factors supported this assumption. First, as previously mentioned, the C compressor was overhauled during the outage and some fouling was found. Second, the B compressor was the only case not opened during the outage, so its cleanliness was unknown. While most of the vibration was indeed

occurring at the running speed (1X) of the compressor, unbalance was not the major contributing cause of the problem. This was ascertained by noting that the large increase in amplitude on the right side of Figure 2 had occurred at relatively constant speed. While it was possible that some fouling material could have been thrown off one of the impellers resulting in a sudden change in balance, this would have been accompanied by a sudden phase shift. However, Figure 2 shows that no such phase shift occurred—the phase remained constant at approximately 215°, eliminating unbalance as the cause of the large observed increase in vibration amplitude. To lend additional credence to this conclusion, an acceptance region plot (i.e., trend of amplitude and phase using polar coordinates) of the bearing #6 y-probe was examined for a data range encompassing the two weeks after startup. It showed that the synchronous phase angle was almost constant (Figure 3).



2. Locked oil seals

The possibility also existed that the floating ring oil seals could have locked in an eccentric position, acting as additional rotor supports instead of just the journal bearings. However, this type of problem would have undoubtedly exhibited some sub-synchronous vibration peaks in the spectrum, because of the oil whirl that would be present in the seals at this speed. Examination of the spectral data showed that the vibration was almost entirely at 1X and had no sub-synchronous components. Consequently, locked seals were extremely unlikely. Additionally, locked seals typically affect the rotor's natural frequencies because they effectively reduce the rotor's span between supports and thus increase its stiffness. Had a change in the compressor's 1st balance resonance been noted (particularly an increase), this would have pointed toward the oil seals. However, comparison of the Bode plot collected prior to the shutdown (Figure 4) with that taken during the post-outage startup (Figure 2) showed that the rotor's first balance resonance had not changed. Combined, the lack of sub-synchronous frequency components and no observed change in the first balance resonance eliminated locked oil seals from further consideration as a likely root cause.

3. Cracked shaft

A cracked shaft will normally be indicated by a decrease in shaft stiffness that results in a noticeable (and sometimes substantial) reduction in the rotor's critical speed. As noted previously by comparing Figures 2 and 4, the rotor's critical speed measured prior to the outage was essentially unchanged from that measured after the outage, making a cracked shaft very unlikely.

4. Internal rub

In contrast to a cracked shaft, a hard rub on internal seals will normally increase the critical speed because of the reduced span between rotor supports, since the seals are now acting as quasi-bearings. For the same reasons listed above, the lack of change in the first balance resonance between the pre-outage coastdown and post-outage startup data did not support a rub hypothesis. Additionally, a rub would normally be observable as flat spots or other anomalies in the shaft orbits. However, the shaft orbits (Figure 5) exhibited no such evidence. Combined, this made a rub extremely unlikely.

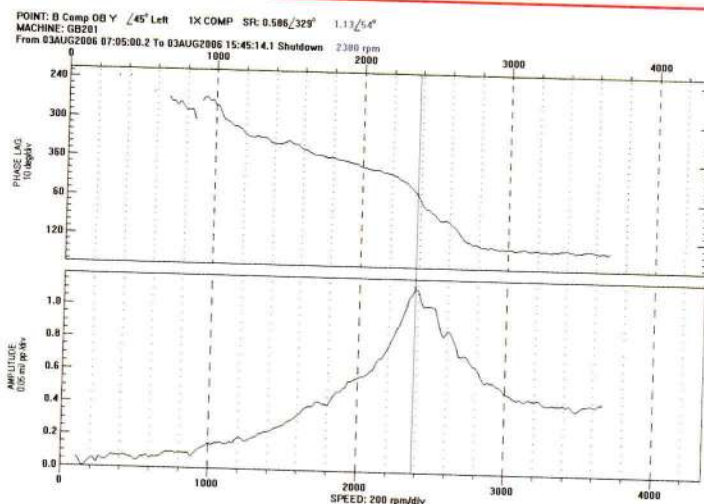


Figure 4. Bode plot of bearing #6 y-probe on shutdown, 8/3/06, prior to the outage. The blue cursor position shows the first balance resonance for this machine occurs at about 2400 rpm, essentially unchanged from the post-outage resonance of Figure 2.

5. Locked Coupling

Although the charge compressor train had a history of locked coupling problems, these had not manifest for several years. After a maintenance turnaround several years prior, the radial vibration on the A and B compressors increased to approximately 3.5 mils, and at the time, it was assumed the problem was caused by coupling lock-up. However, the vibration had trended down to normal levels over time. Additionally, the couplings removed during the August 2006 outage did show indication of wear between the end of the hubs and spacer, and for this reason were replaced with identical new components. The fact that the couplings were brand new seemed to rule out the likelihood of coupling lock-up. Likewise, the alignment of the compressor had been checked and found to be in good condition. Measurements had been taken in the past that showed the thermal growth assumptions in the cold alignment targets were good.

For all of these reasons, the coupling was not immediately suspect.

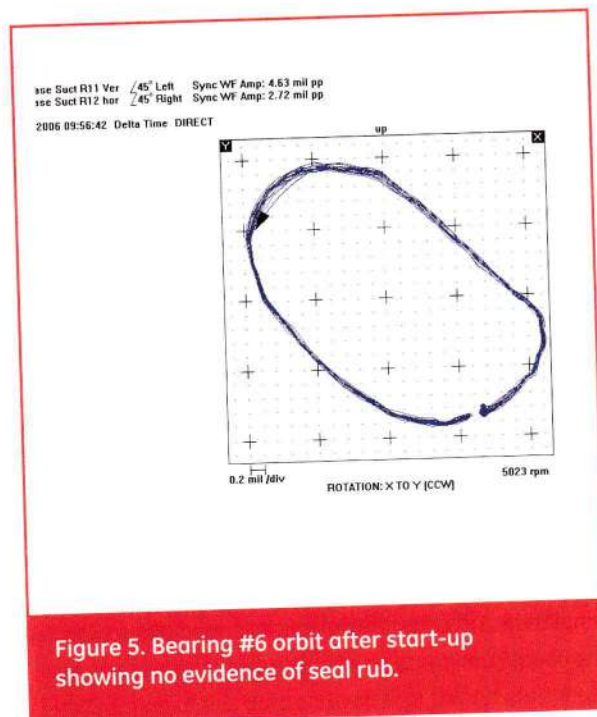


Figure 5. Bearing #6 orbit after start-up showing no evidence of seal rub.

IN THIS SPECIFIC INCIDENT,
THE ABILITY TO ACCURATELY
DIAGNOSE THE ROOT CAUSE
ALLOWED MACHINERY
PERSONNEL TO RECOMMEND
A REDUCED WORK SCOPE.
THIS SAVED APPROXIMATELY
10-11 DAYS OF LOST
PRODUCTION WHEN
COMPARED WITH A COMPLETE
OVERHAUL THAT WOULD
HAVE BEEN REQUIRED IN THE
ABSENCE OF SUCH DATA.

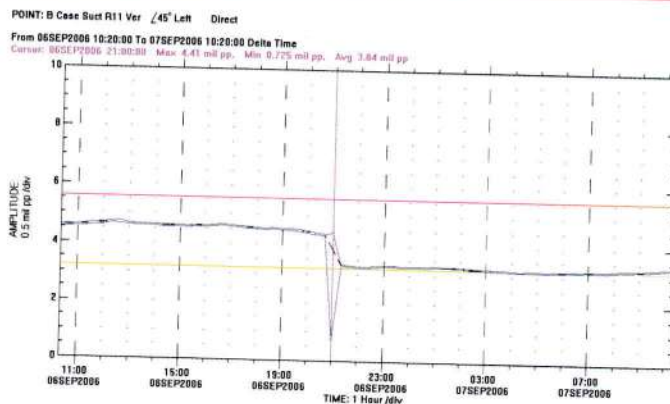


Figure 6. Rapid drop in bearing #6 y-probe unfiltered overall vibration amplitude during speed upset. Note that following the event, the amplitude returns to nearly the same level as prior to the speed upset.

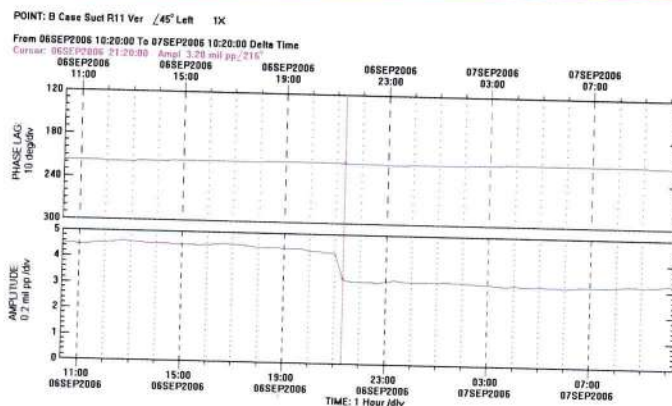


Figure 7. Same data as in Figure 6, but filtered to compressor running speed (1X).

The first strong indication that the coupling might be the problem after all came approximately one week after the startup. Because of a governor control oil problem, the turbine speed dropped rapidly (from approximately 5000 to 3500 rpm in a few seconds). When this occurred, the overall radial vibration at bearing #6 dropped from approximately 4.5 mils to 0.7 mils. However, the speed returned almost as quickly as it had dropped, and the high vibration returned (Figure 6). Initially, this event was not that enlightening because the 1X trend (see Figure 7) seemed to indicate that the synchronous amplitude and phase angle had not changed markedly, in stark contrast to the changes observed in the overall unfiltered

vibration of Figure 6. However, after contacting GE's Bently Nevada Machinery Diagnostic Services (MDS) personnel, it was learned that the overall value displayed in the DM2000 software is received directly from the 3500 series machinery protection system and merely "passed through," while the 1X value is calculated in the software from the raw vibration waveform. Since the change in speed and vibration happened so rapidly, the DM2000 software's tracking filter was not fast enough to capture this rapid excursion. Thus, it seemed likely that the 1X amplitude and phase had in fact changed along with the overall unfiltered amplitude during this excursion.

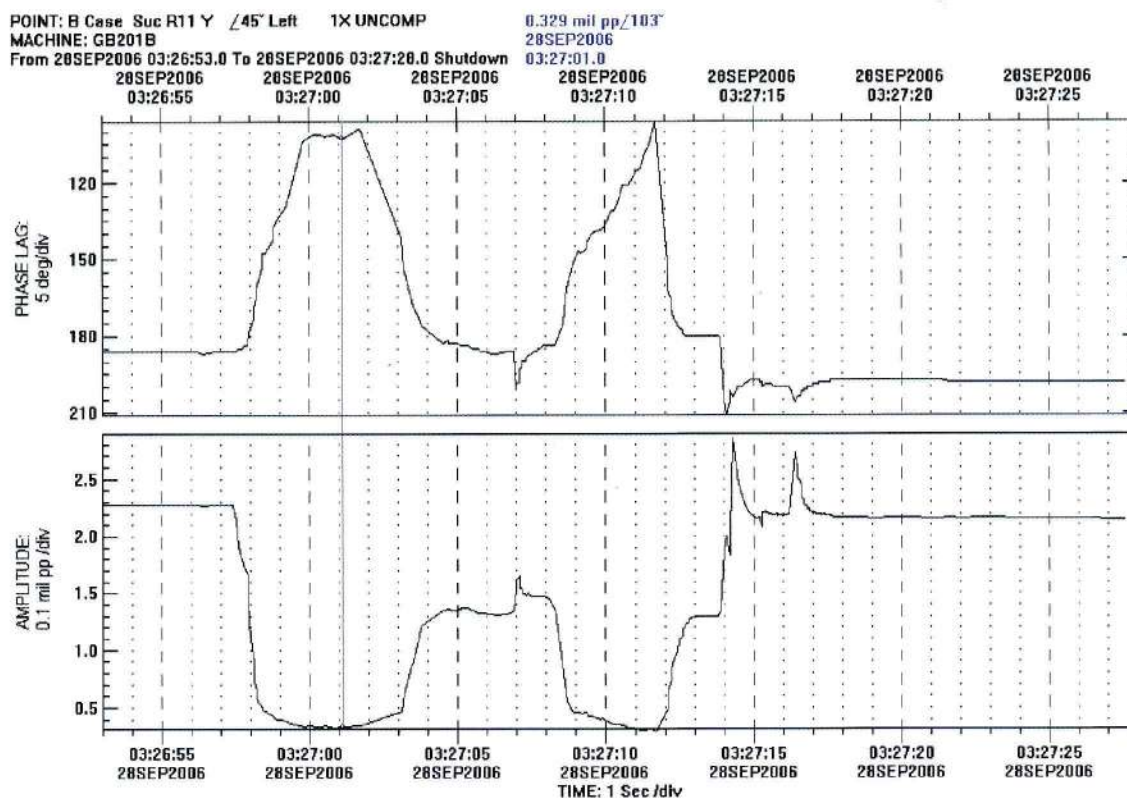


Figure 8. Bearing #6 y-probe 1X filtered amplitude and phase data collected during surge events on 9/28/06. Note high-resolution time span on horizontal axis (1 second per division) indicating that the back-to-back surge events occurred within approximately 10 seconds of one another.

In an attempt to re-create the drop in vibration mentioned above, approximately one month after the outage, the compressor speed and load were decreased during a reduction in unit rates. During this test, an ADRE portable data acquisition system was connected to the 3500 machinery protection rack as it provided higher data resolution than the DM2000 software. Because the speed decrease was gradual, there was no rapid decrease in vibration as seen earlier. However, during the reduction in unit rates, the compressor was accidentally surged and because the ADRE system was connected, high resolution data was acquired. Examination of this data showed that the synchronous

amplitude had dropped rapidly during the two surge events. Likewise, the synchronous phase angle had changed as well (Figure 8). These facts pointed strongly to the likelihood that the coupling between the B and C compressors was locked in a rigid condition, but had momentarily "broken free" during the surge event because of the rapid flow reversal and subsequent relaxation of torsional loading on the coupling.

POINT: B Comp OB Y / 45° Left REF: -9.20 Volts
 POINT: B Comp OB X / 45° Right REF: -9.74 Volts
 MACHINE: G8201
 From 03AUG2006 07:05:00.2 To 03AUG2006 15:45:14.1 Shutdown
 [not orbit or polar plot]

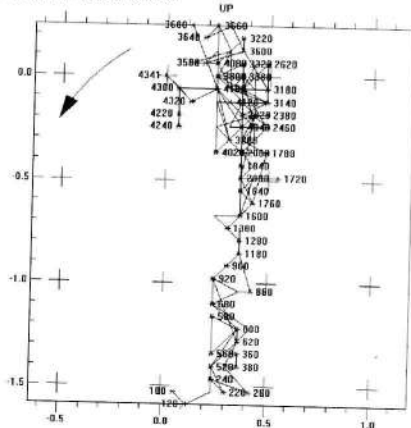


Figure 9. Shaft centerline plot for bearing #6 during pre-outage shutdown on 8/3/2006.

POINT: B Comp OB Y / 45° Left REF: -9.47 Volts
 POINT: B Comp OB X / 45° Right REF: -9.20 Volts
 MACHINE: G8201
 From 27AUG2006 09:26:46.2 To 27AUG2006 16:02:43.6 Startup
 [not orbit or polar plot]

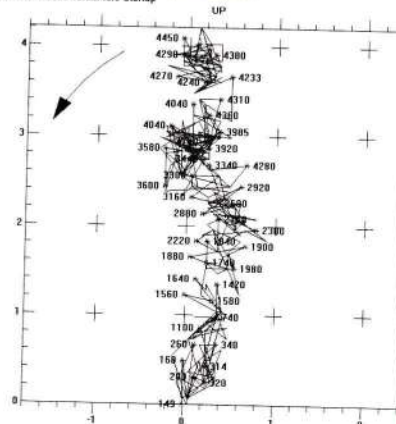


Figure 10. Shaft centerline plot for bearing #6 during post-outage startup on 8/27/2006.

Examination of the shaft centerline plots of the #6 bearing revealed that the journal had dropped approximately 2.0 mils during the coast-down before the outage, but had raised 4.0 mils during the subsequent start-up (see Figures 9 and 10 respectively). This meant that the suction end journal was riding in the center of the bearing, instead of the lower half, since the design bearing clearance was approximately 8 mils. The indication was that something was lifting the B compressor suction end journal off of its bearing. This was further confirmed by examination of the bearing metal temperatures for bearing #6 (see Figure 11). As can be seen, the bearing #6 temperature is approximately 15° cooler after the mitigation outage, even though the vibration was obviously higher. In contrast, the bearing #7 temperature was approximately the same before and after the outage, indicating that no other external factors, such as oil temperature or ambient temperatures, were affecting the results.

THIS TEST WAS A FURTHER
 CONFIRMATION THAT THE B
 COMPRESSOR ROTOR WAS
 BEING LIFTED OFF BEARING
 #6 BY A RIGID COUPLING
 BETWEEN THE B AND C
 COMPRESSORS.

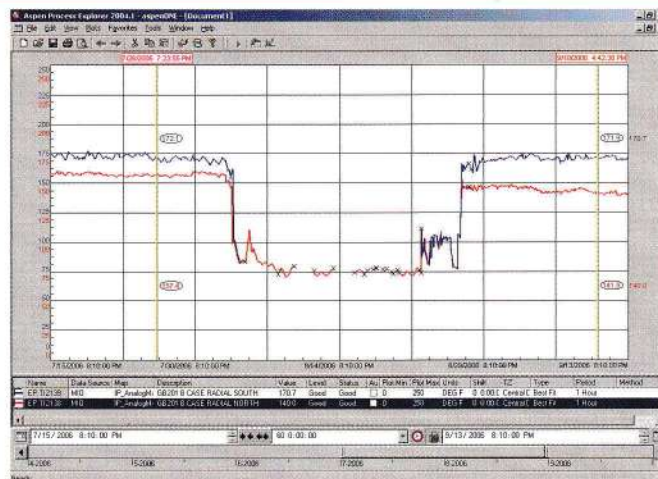


Figure 11. Trend from the plant's process historian showing bearing #6 (red) and bearing #7 (blue) temperatures before and after outage. Note that the temperature of bearing #6 drops approximately 15 degrees after the outage, while the temperature of bearing #7 stays approximately the same. This helped corroborate that bearing #6 was more lightly loaded and riding more towards the center of its clearance (i.e., lower eccentricity ratio) after the outage.

Validation

In an attempt to reduce the radial vibration amplitude at bearing #6, and confirm that the low journal eccentricity was associated with the problem, an online test was conducted to change the relative vertical alignment between the B and C compressors. The basic concept was to "pull" the B suction end journal down further in its bearing, thereby increasing its eccentricity and bearing stiffness and reducing the radial vibration. This was accomplished by using an air mover with water spray on the discharge foot of the C compressor, and a steam hose on the suction pedestal of the B compressor. The objective was to change the alignment, lowering the C case discharge end and raising the B case suction end (Figure 12). Because heating and cooling effects were localized to the compressor supports, it did not change the bearing housing temperature, which potentially could have skewed the shaft centerline plots due to the probes "growing away from the shaft."

The changes had exactly the effect predicted. The shaft centerline plots of bearings #6 and #7 are shown in

Figure 13. Likewise, the reduction in radial vibration is shown in Figure 14. This test was a further confirmation that the B compressor rotor was being lifted off bearing #6 by a rigid coupling between the B and C compressors.

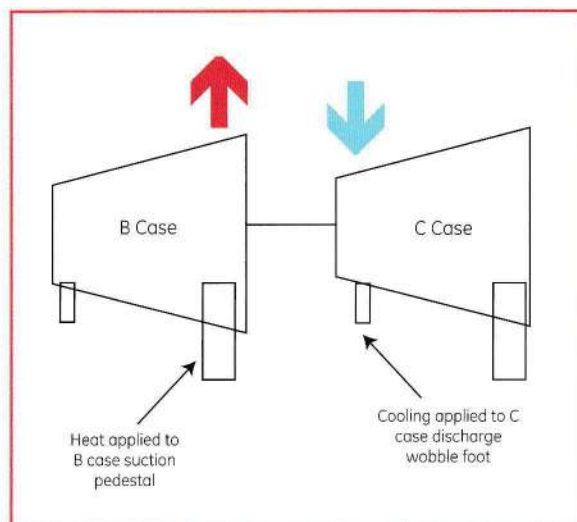


Figure 12. Graphical depiction of online alignment adjustments used to confirm the locked coupling postulate.

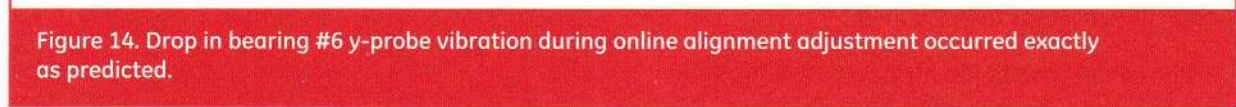




Figure 15. November 2006 photo showing replaced gear coupling between B and C compressor bodies. Abnormal wear is clearly evident after only 2 months of operation.

The high-resolution data (Figure 8) taken during the compressor surge showing the rapid synchronous phase change, and the drop in vibration (Figure 14) observed during the online alignment change all indicated that coupling lock-up was the problem. Approximately two months after the outage, the overall vibration at bearing #6 was still trending above 4 mils with occasional excursions above 5 mils.

Corrective Actions

Another outage was planned in the winter months to address the vibration issue. Due to the isolation requirements of the compressor, the couplings could be changed without completely clearing the compressors. This would allow the compressor to be ready for maintenance approximately one day after the unit was shut down. In contrast, if the case had to be opened, this would require a minimum of 4 days just to clear the compressor cases before maintenance work could begin. The end result was that a coupling change could be accomplished with 3 to 4 days of interrupted production, while a complete overhaul would require at least 2 weeks, incurring 10 or more days of additional downtime. While this made the coupling work look very attractive, the prospect of changing only the coupling, restarting the compressors, and then discovering that

the high vibration was still present was highly undesirable. For this reason, some advocated the safe route of a complete overhaul. However, based on the clear indication of the coupling lock-up from the test data, the site machinery personnel were able to alleviate management's concerns and reduce the work scope to that of just replacing the couplings.

Results

The charge gas compressor train was brought down and the last two gear couplings in the train were replaced with dry, flex-element style couplings. As expected, the vibration on bearing #6 returned to normal levels of approximately 0.5 mils. Figure 15 shows the gear coupling removed from between the B and C compressor bodies. It clearly exhibits an abnormal wear pattern considering it had only been in operation for approximately two months.

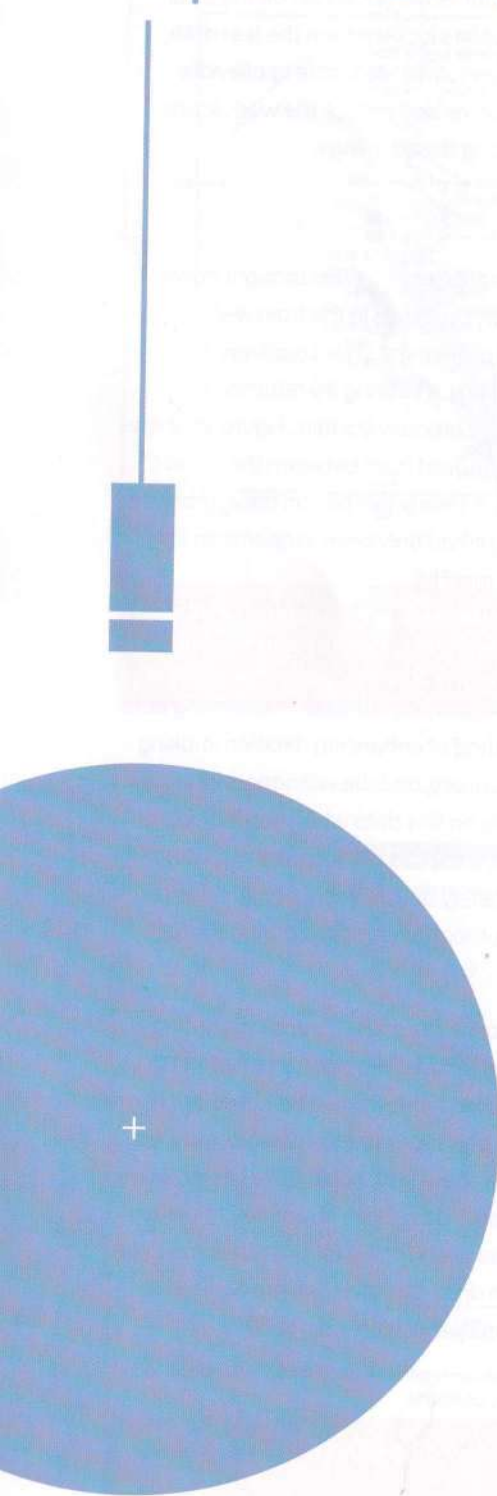
Conclusions

Chevron is increasingly using condition monitoring data as an effective method of enhancing decision-making confidence and accuracy, and the willingness of plant management to rely on this data when making operating and maintenance decisions is increasing as well. This case history was merely one example of more than half a dozen that the author has compiled during the last several years.

In this specific incident, the ability to accurately diagnose the root cause allowed machinery personnel to recommend a reduced work scope. This saved approximately 10-11 days of lost production when compared with a complete overhaul that would have been required in the absence of such data. Each day of downtime typically costs in excess of 200K USD for this plant, meaning that several million dollars in savings were realized due to accurate and timely machinery data. **U**

* denotes the trademarks or registered trademarks of Bently Nevada, LLC, a General Electric company.

Optimizing Gap Alarm Settings



Prior to 3500 Rack Configuration software version 3.86, proximity probe monitors in our 3500 series system had the gap alarms enabled by default with gap voltage limits set at -15.6 and -8.4 vDC. This range of voltage, with a 200 mV/mil scale factor, represents 36 mils of total possible motion. These default values were merely that: default settings that must be configured before use.

In many cases, the default values may not be appropriate for the machine. In all cases, they must be reviewed by a knowledgeable individual and configured appropriately based on the specifics of each machine. When this is not done, or when the default values are relied upon without confirming their adequacy, it can lead to a false sense of security or nuisance alarms. In many machines, particularly those with relatively small bearing clearances (as compared to 36 mils), these values can permit a considerable amount of bearing "wiping" to occur before the alarm limit is encountered.

To address this situation and prevent users from automatically using gap alarms that may be inappropriate, versions of 3500 Rack Configuration software 3.86 and newer now disable the gap alarms as default.

Fortunately, using readily available machine information, the gap alarm settings can be optimized for specific bearings and the anticipated shaft centerline motion. This article describes the recommended procedure for setting these gap alarms, as detailed next.

[Editor's Note: Although the recommendations here specifically refer to 3500 monitoring systems and software, the general principles imparted can be used on any Bently Nevada* monitoring system with gap alarm capabilities, such as 3300/16 radial vibration monitors. It can also be used to establish such alarms in condition monitoring software, such as System 1.]

John Winterton – Principal Machinery Diagnostics Engineer – Bently Nevada Asset Condition Monitoring – GE Energy – john.winterton@ge.com

Required Information

The information necessary to establish appropriate gap alarms consists of three main items as follows:

1. Gap voltages at a shutdown (i.e., rotor standstill) condition. In machines with rigidly coupled shafting, this may require breaking couplings in order to positively determine the proximity probe gap voltages with the shaft at the bottom of the bearing.
2. Transducer mounting angles of a pair of orthogonal probes.
3. The nominal or actual bearing clearance.

Ideally, the capabilities within GE's Bently Nevada* System 1* or ADRE* software packages would be utilized to acquire and portray these variables in a standard shaft centerline plot; however, these variables can also be plotted graphically and yield the information to properly utilize the gap alarm function with the 3500 rack. With relatively simple instrumentation such as an appropriately selected digital voltmeter, the necessary data can be collected and gap alarms established that are appropriate to any given bearing.

Transducer/Bearing Geometries and Mathematical Relationships

Fundamentally, the procedure for determining allowable gap involves plotting the shutdown position of the rotor within the bearing, expressed as a gap voltage measured by the "X" and "Y" orthogonal transducers. Using the nominal or actual bearing clearance, the theoretical voltages with the rotor positioned in the center of the bearing clearance circle are established. Then, it is a relatively simple matter to theoretically displace the rotor to the extremes of travel relative to a transducer, while establishing the voltages at the extreme positions using simple mathematics and the transducer scale factor.

The change in gap for each transducer of an orthogonal pair can be expressed as Equation 1 (Hatch [1]).

$$\Delta \text{GAP} = -R_s - C_s \cos(\phi) + \sqrt{R_s^2 - C_s^2 \sin^2(\phi)} \text{ mils} \quad [1]$$

where R_s = shaft radius (mils)
 C_s = nominal radial clearance (mils)
 ϕ = angle of probe orientation measured from the vertical, positive clockwise

As an example, transducers mounted at 45° left and right of top dead center, monitoring a 6.000 inch shaft supported in a bearing with 8.5 mils of diametral clearance will undergo a -3.0077 mil change in gap when the shaft is moved to the center of the bearing bore, e. g., straight up 4.25 mils.

Equation 1 is correct for two circles of differing diameters, one within the other, and accounts for the fact that the radius of curvature is different for the two circles. The equation, however, is complex. As such, it can easily result in errors.

For most situations, $R_s \gg C_s$ by several orders of magnitude. Thus, Equation 1 can be simplified for use in most practical situations as follows:

$$\begin{aligned} \Delta \text{GAP} &= -R_s - C_s \cos(\phi) + \sqrt{R_s^2 - C_s^2 \sin^2(\phi)} \text{ mils} \\ &\approx -R_s - C_s \cos(\phi) + \sqrt{R_s^2} \\ &\approx -R_s - C_s \cos(\phi) + R_s \\ &\approx -C_s \cos(\phi) \text{ mils} \end{aligned} \quad [2]$$

Accordingly, a simplified approach using estimation for the change in gap (ΔGAP) can be readily accomplished with minimal error in the calculation, and is the basis for the method discussed next.

Simplified Method

As before, this procedure involves plotting the shutdown position of the rotor within the bearing, expressed as a gap voltage measured by the "X" and "Y" orthogonal transducers. It is assumed that when at rest, the rotor is positioned at the bottom of the bearing clearance boundary. The shaft is then, in a virtual sense, displaced to the center of the bearing, and new gap voltages are calculated for each of the transducers. Knowing the bearing clearance, and realizing that the "virtual" rotor shaft is in the center of the bearing, it is a simple matter to then calculate transducer gap voltages at the closest and furthest points of approach to a particular transducer. These voltages, with respect to a selected transducer, represent the voltages for the rotor at an eccentricity of 1.0 (i.e., contact with the bearing wall).

Example

Refer to Figure 1 where a pair of orthogonal proximity probes are shown at 20° left of top dead center and 70° right of top dead center. A bearing diametral clearance of 9.5 mils is assumed. Note that it is not necessary to know the journal diameter.

For the purpose of this example, polar plotting paper is used, however, if the process is clear to the user, a simple sketch can suffice.

Procedure:

1. On polar paper, draw a circle scaled to represent the bearing clearance boundary. Referring to Figure 1, this is the red circle. The black circle shown on Figure 1 represents the journal; but again, it is not necessary to know the journal diameter.

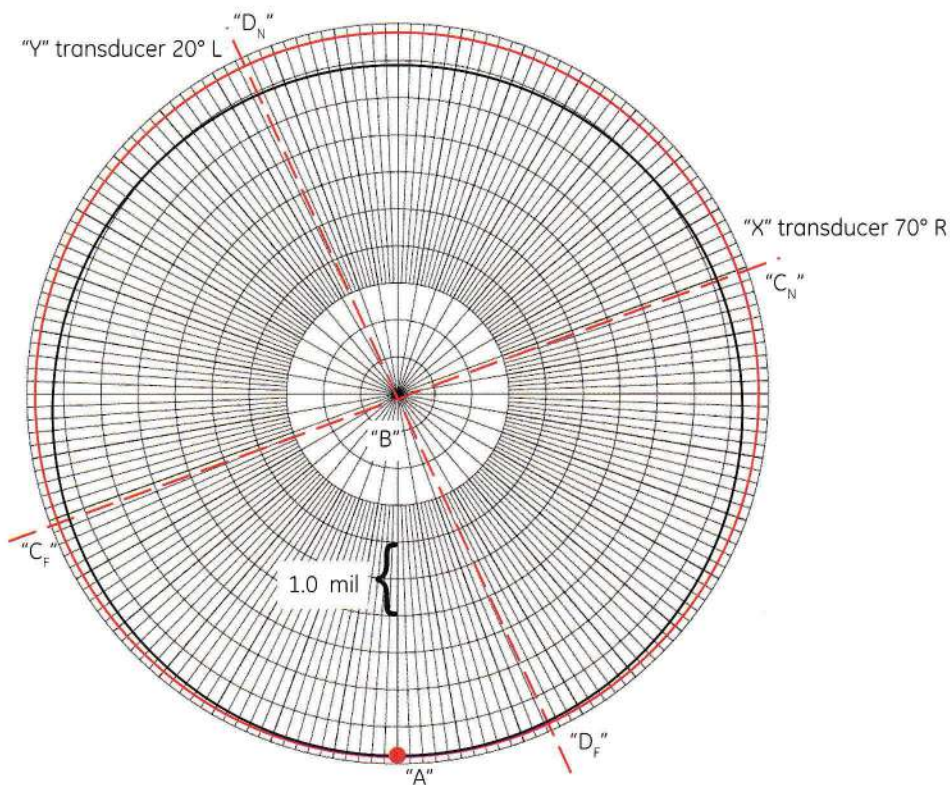


Figure 1. Gap Alarm Voltage Analysis.

- Establish the shutdown gap voltages at position "A" as shown on Figure 1. These are the voltages with the rotor at the bottom of the clearance boundary. For our example, the voltages are:

$$X \text{ transducer} = -10.130 \text{ vDC}$$

$$Y \text{ transducer} = -9.925 \text{ vDC}$$

and the diametral bearing clearance is 9.5 mils.

- Calculate the voltages when the shaft is, in theory, displaced to the center of the clearance boundary (position "B" shown on Figure 1). This is accomplished using a simple trigonometry function applied to the transducer-mounting angle. In a general sense, the equation is expressed as Equation 3.

$$V = -V_{REF} + V_C \cos(\phi) \text{mils} \quad [3]$$

where:

V_{REF} = DC voltage from any given transducer with shaft at the bottom of the bearing

V_C = voltage equivalent to the *radial* clearance (vDC)

ϕ = angle of probe orientation measured from the vertical, positive clockwise

For our example, the voltages with the shaft at the center of the bearing (position "B" in Figure 1) are calculated as follows using Equation 2.

$$V_X = -10.130 + 0.95 \cos 70^\circ = -9.805$$

$$V_Y = -9.925 + 0.95 \cos 340^\circ = -9.032$$

- Calculate the voltages with the shaft at the bearing wall nearest the "X" transducer (position "C_N" in Figure 1). This is the voltage with the rotor at center of the bore, referenced to the "X" transducer, added to the change in voltage anticipated when the journal moves to the point closest to the "X" transducer. In this example, for the "X" transducer

$$V_{XN} = -9.805 + 0.95 = -8.855.$$

- In similar manner calculate the voltages with the shaft at far bearing wall farthest away from the "X" transducer (position "C_F" in Figure 1). This is the volt-

age with the rotor at center of the bore, referenced to the "X" transducer, added to the change in voltage anticipated when the journal moves to the point furthest away from the "X" transducer. In this example, for the "X" transducer

$$V_{XF} = -9.805 - 0.95 = -10.755.$$

Note that it is important to pay careful attention to the sign of the voltage change represented by the journal movement. In step 4, the sign of the voltage change (0.95) is positive since the journal moves closer to the transducer. Hence, the voltage change is more positive. In contrast, in step 5, the sign of the voltage change (0.95) is negative since the journal moves away from the transducer. Hence, the voltage change is more negative.

In similar manner, the near and far point voltages with respect to the "Y" transducer can be calculated.

Calculated voltage, shaft at near wall "Y" transducer, position "D_N"

$$V_{YN} = -9.032 + 0.950 = -8.082$$

Calculated voltage, shaft at far wall "Y" transducer, position "D_F"

$$V_{YF} = -9.032 - 0.950 = -9.982$$

...USING READILY AVAILABLE
MACHINE INFORMATION,
THE GAP ALARM SETTINGS
CAN BE OPTIMIZED FOR
SPECIFIC BEARINGS AND
THE ANTICIPATED SHAFT
CENTERLINE MOTION.

Transducer	3500 Rack		Bearing Diametral Clearance (mils)	Shutdown Reference Voltage (VDC)	Near Wall voltage (VDC)	Far Wall voltage (VDC)	Near Wall voltage setpoint 5 mil "wipe"	Far Wall voltage setpoint 5 mil "wipe"	Near Wall voltage setpoint 10 mil "wipe"	Far Wall voltage setpoint 10 mil "wipe"
	Slot	Channel								
Motor NDE X	3	1	8.5	-9.88	-8.429	-10.129	-7.43	-11.13	-6.43	-12.13
Motor NDE Y	3	2	8.5	-9.891	-8.44	-10.14	-7.44	-11.14	-6.44	-12.14
Motor DE X	3	3	8.5	-9.878	-8.427	-10.127	-7.43	-11.13	-6.43	-12.13
Motor DE Y	3	4	8.5	-9.773	-8.322	-10.022	-7.32	-11.02	-6.32	-12.02
LSS DE X	4	1	9.5	-10.13	-8.855	-10.755	-7.86	-11.76	-6.86	-12.76
LSS DE Y	4	2	9.5	-9.925	-8.082	-9.982	-7.08	-10.98	-6.08	-11.98
LSS NDE X	4	3	9.5	-9.055	-7.78	-9.68	-6.78	-10.68	-5.78	-11.68
LSS NDE Y	4	4	9.5	-9.703	-7.86	-9.76	-6.86	-10.76	-5.86	-11.76
HSS NDE X	5	1	11	-9.089	-6.926	-9.126	-5.93	-10.13	-4.93	-11.13
HSS NDE Y	5	2	11	-9.202	-7.817	-10.017	-6.82	-11.02	-5.82	-12.02
HSS DE X	5	3	11	-10.17	-8.007	-10.207	7.01	-11.21	-6.01	-12.21
HSS DE Y	5	4	11	-9.404	-8.019	-10.219	-7.02	-11.22	-6.02	-12.22
COMP DE X	6	1	6	-9.995	-8.971	-10.171	-7.97	-11.17	-6.97	-12.17
COMP DE Y	6	2	6	-10.001	-8.977	-10.177	-7.98	-11.18	-6.98	-12.18
COMP NDE X	6	3	6	-9.871	-8.847	-10.047	-7.85	-11.05	-6.85	-12.05
COMP NDE Y	6	4	6	-10.215	-9.191	-10.391	-8.19	-11.39	-7.19	-12.39

Anticipated voltages at point of contact with bearing wall
 Anticipated voltages with 5 mils of wiping into the bearing babbit
 Anticipated voltages with 10 mils of wiping into the bearing babbit

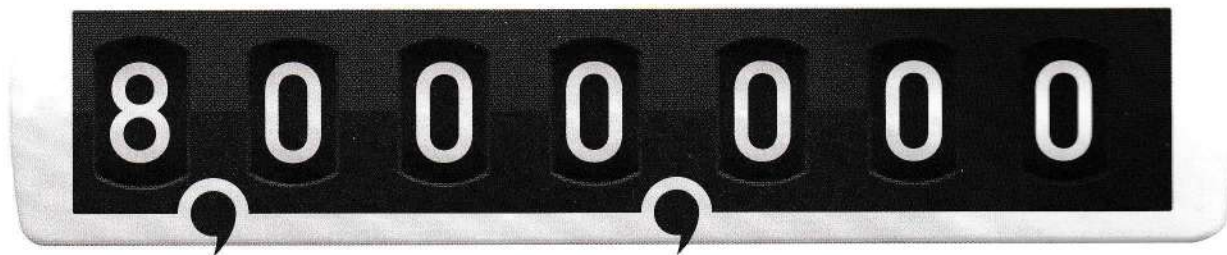
Figure 2. Summary of gap alarm voltage setpoints.

Once the near and far point voltages are established for each transducer, it is possible to set up manually (or in a spreadsheet) a tabular list showing the anticipated voltages with a 5 mil wipe or a 10 mil wipe into the bearing babbit. These voltages are then utilized to provide optimized gap alarms based on the actual machine characteristics. However, knowledge of the bearing is required since babbit thicknesses vary considerably. A sample table of voltages is shown in Figure 2. 

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References

- [1] Personal e-mail correspondence with Charles T. Hatch (charles.hatch@ge.com), GE Energy, 4/25/2008



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